Lloyd's Register

Rules for the Manufacture, Testing and Certification of Materials, July 2009

Notice No. 1

Effective Date of Latest Amendments:

See page 1

Issue date: January 2010

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RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS, *July 2009*

Notice No. 1

This Notice contains amendments within the following Sections of the *Rules for the Manufacture, Testing and Certification of Materials, July 2009.* The amendments are effective on the dates shown:

Chapter	***Section***	***Effective date***
1	3, 4, 5	1 July 2010
3	1, 2, 3, 4, 5, 6 7, 8, 9, 10	1 July 2010
4	1, 2, 4, 5, 9	1 July 2010
5	1, 2, 3, 4	1 July 2010
6	1, 5	1 July 2010
7	1, 2, 3, 4	1 July 2010
8	1, 2, 3, 4	1 July 2010
9	1, 2, 3	1 July 2010
11	1, 3, 4, 5, 6 7, 8, 9	1 July 2010
12	2, 4, 5	1 July 2010
13	1, 2, 4, 5	1 July 2010
14	1, 2, 3, 5	1 July 2010

It will be noted that the amendments also include corrigenda, which are effective from the date of this Notice.

The *Rules for the Manufacture, Testing and Certification of Materials July 2009* are to be read in conjunction with this Notice No. 1. The status of the Rules is now:

Rules for Materials	Effective date:	July 2009
Notice No. 1	Effective date:	1 July 2010 & Corrigenda

Chapter 1

General Requirements

Effective date 1 July 2010

■ *Section 3*

Certification of materials

3.1 General

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that ~~a copy~~ two copies of the certificate ~~is~~ are supplied to LR.

■ *Section 4*

General requirements for manufacture

~~4.7 Visual and non-destructive examination~~

~~*4.7.1* Prior to the final acceptance of materials, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in subsequent Chapters of these Rules.~~

~~*4.7.2* The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.~~

~~*4.7.3* When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by any suitable method.~~

Existing sub-Section 4.8 *is to be renumbered* 4.7.

~~4.9~~ 4.8 Identification of materials

Existing paragraphs 4.9.1 *and* 4.9.2 *are to be renumbered* 4.8.1 *and* 4.8.2.

4.8.3 Where hard stamps such as the LR brand stamp are issued to manufacturers to carry out the stamping on behalf of LR, the procedure for issue, maintenance and use of stamps is to be agreed in writing.

Existing paragraphs 4.9.3 *and* 4.9.4 *are to be renumbered* 4.8.4 *and* 4.8.5.

■ *Section 5*

Non-destructive examination

5.1 General NDE requirements

5.1.1 Prior to the final acceptance of materials, surface inspection and verification of dimensions, non-destructive examination is to be carried out in accordance with the requirements detailed in this Section and subsequent Chapters of these Rules.

5.1.2 It is the manufacturer's responsibility for maintaining the required tolerances and making the necessary measurements. Periodic surveys by the Surveyor do not absolve the manufacturer from this responsibility.

5.1.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by a suitable method.

5.1.4 Acceptance criteria are detailed in subsequent Chapters of these Rules. Alternative specifications may be submitted for consideration, provided they demonstrate equivalence to these Rules.

5.2 Personnel qualifications

5.2.1 The shipyard, fabricator or manufacturer is to ensure that personnel carrying out non-destructive examination or interpreting the results of non-destructive examination are qualified to the appropriate level of a nationally recognised scheme such as ISO 9712, EN 473, PCN, ACCP or SNT-TC-1A. Level 1 personnel are not permitted to interpret results to Codes or Standards.

5.2.2 When certification of personnel is made on an in-house basis under a scheme such as SNT-TC-1A, practical examinations are to be relevant to material, product type, joint configuration, material thickness and acceptance criteria of items inspected for Classification purposes.

5.2.3 Personnel qualifications of NDE operators are to be randomly checked by the Surveyor.

5.3 Non-destructive examination methods

5.3.1 Non-destructive examination methods are to comply with the relevant requirements of these Rules.

5.4 Non-destructive examination procedures

5.4.1 All non-destructive examinations are to be carried out to a procedure that is representative of the item under inspection. As a minimum the procedures are to be in accordance with the following:

(a) Procedures are to identify the component to be examined, the NDE method, equipment to be used and the full extent of the examinations including any test restrictions.
(b) Procedures are to specify the qualification and certification requirements of the inspection personnel to be employed.
(c) Procedures are to state the degree of surface preparation required and the methods of preparation to be used before the examinations are made.
(d) Procedures are to state the reference standards for testing and the acceptance criteria to be applied to the results of the inspections.
(e) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
(f) Procedures are to identify any requirements for increasing the extent of applied NDE where defects have been found during spot examination.
(g) Procedures are to identify reporting requirements.
(h) Procedures are to be reviewed by the Surveyor to ensure they are appropriate for the product type.
(j) Procedures for radiography are to specify the acceptable optical density within the area of interest on the radiograph.
(k) Procedures are to include the method and requirements for equipment calibrations and functional checks.

5.4.2 The shipyard, fabricator or manufacturer may submit other Codes or Standards for consideration by LR, providing they meet the requirements of these Rules.

5.5 Non-destructive examination reports

5.5.1 NDE reports are to include all information required to identify how the examination was executed and are to include the following information where appropriate:
(a) Date of test.
(b) Name and qualification of operator with signatures of the operator.
(c) Details of the component identification, description of test location and volume examined.
(d) Heat treatment status.
(e) Weld type, procedure and configuration.
(f) Surface condition.
(g) Test procedure.
(h) Equipment used.
(j) Test results with a map or record of any defects, giving location, dimensions and defect nature.
(k) Reference to acceptance criteria and evaluation in accordance to these criteria.
(l) Material type and thickness.
(m) Calibration.

Chapter 3

Rolled Steel Plates, Strip, Sections and Bars

Effective date 1 July 2010

■ *Section 1*
General requirements

1.1 Scope

1.1.6 Steels intended for high heat input welding above 50 kJ/cm are to be specially approved. Approval will be indicated on the manufacturer's approval certificate by adding a high heat input welding notation to the grade approved e.g. EH36-W300, indicating approval up to 300 kJ/cm.

1.3 Manufacture

1.3.4 Material may be supplied either as-rolled, normalised, normalising rolled, or thermomechanically controlled rolled. The following definitions apply:
(a) As-rolled (AR) refers to ~~products that are supplied without any heat treatment after completion of the rolling operations. The rolling temperature and reduction may not be strictly controlled resulting in a variable grain size.~~ rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than those of steel heat treated after rolling or steel produced by advanced processes.
(b) Normalising (N) ~~is a separate austenitising heat treatment after rolling which refines the grain size, improving the mechanical properties.~~ refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

(c) Normalising rolling (NR) ~~is a procedure in which the final deformation is carried out in the normalising temperature range resulting in a material condition equivalent to that obtained by normalising. Normalising rolling may, therefore, be acceptable as a direct equivalent of a normalising heat treatment.~~ , also known as controlled rolling, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(d) Thermomechanically controlled rolling (TM) is a procedure ~~in which both the temperatures and thickness reductions are strictly controlled and in which rolling is completed at a specified temperature close to, and may be less than, that at which ferrite formation is complete. This results in a microstructure and mechanical properties which cannot be obtained by a normalising heat treatment.~~ which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike normalising rolling the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM may also be accepted subject to the special approval by LR.

(e) Accelerated Cooling, (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other austenitising heat treatment.

~~(e)~~ (f) Quenching and Tempering (QT) ~~involves quenching,~~ is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

~~*1.3.6* The mechanical properties may be improved by means of accelerated cooling which involves controlled cooling, at rates higher than are obtained by air cooling, after the final rolling operation. Materials may be supplied in this condition subject to approval by LR. Accelerated cooling does not include quenching and the mechanical properties conferred by it cannot be reproduced by subsequent normalising or other heat treatment.~~

Existing paragraph 1.3.7 *is to be renumbered* 1.3.6.

1.7 Test material and mechanical tests

1.7.3 The test material is to be taken from the thickest piece in each batch, *see* Ch 1,4.1.

1.11 Certification of materials

(Part only shown)

1.11.1 ~~Each test certificate~~ Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and is to include the following particulars:

■ *Section 2*
Normal strength steels for ship and other structural applications

2.4 Mechanical tests

Table 3.2.3 Mechanical properties for acceptance purposes (*Part only shown*)

<table>
<tr><th rowspan="3">Grade</th><th rowspan="3">Yield stress N/mm^2 minimum</th><th rowspan="3">Tensile strength N/mm^2</th><th rowspan="3">Elongation on $5{,}65\sqrt{S_o}$ % minimum</th><th colspan="3">Charpy V-notch impact test (<i>see</i> Notes 3, 4, 5, 6 and 7)</th></tr>
<tr><th rowspan="2">Thickness mm</th><th colspan="2">Average energy J minimum</th></tr>
<tr><th>Longitudinal</th><th>Transverse (<i>see</i> Note 3)</th></tr>
<tr><td colspan="4">Impact tests are to be made on the various grades at the following temperatures:</td><td>A grade
B grade
D grade
E grade</td><td>~~20°C~~ not required
0°C
–20°C
–40°C</td><td></td></tr>
<tr><td colspan="7">NOTES
3. ~~Generally, tests need only be made in the longitudinal direction. For special applications, transverse test specimens may be required by the purchaser or LR. Transverse test results for plates and wide flats are to be guaranteed by the supplier.~~ Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.</td></tr>
</table>

2.6 Certification of materials

2.6.1 At least two copies of each test certificate ~~or shipping statement~~ are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. ~~The chemical composition is to include the content of all the elements~~ As a minimum, the chemical composition is to include the contents of any grain refining elements used and the residual elements, as detailed in Table 3.2.1.

■ *Section 3*
Higher strength steels for ship and other structural applications

3.4 Chemical composition

Table 3.3.2 Chemical composition (*Part only shown*)

Grades	AH, DH, EH	FH
Grain refining elements (*see* Note 2)		
Aluminium (acid soluble) %	0,015 min. (*see* Note 3)	
Niobium %	0,02 – 0,05	
Vanadium %	~~0,03~~ 0,05 – 0,10	
Titanium %	0,02 max.	
Total (Nb + V + Ti) % (*see* Note 5)	0,12 max.	

Table 3.3.4 Conditions of supply for plates and wide flats (*Part only shown*)

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 40	Any practice	≤12,5	AR	N	NR	TM	
		>12,5 ≤~~100~~ 50	—	N	NR	TM	
		>50 ≤100	—	N	—	TM	QT
DH 40	Any practice	≤50	—	N	NR	TM	
		>50 ≤100	—	N	~~NR~~	TM	QT

3.6 Mechanical tests

Table 3.3.6 Mechanical properties for acceptance purposes (*see* Note 1) (*Part only shown*)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 3, 4 and 5)					
				Average energy J minimum					
				$t \le 50$ mm		$50 < t \le 70$ mm		$70 < t \le 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 32 DH 32 EH 32 FH 32	315	440 – ~~590~~ 570	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – ~~620~~ 630 ~~(see Note 3)~~	21	34	24	41	27	50	34

NOTES

4. ~~Generally, tests need only be made in the longitudinal direction. For special applications, transverse test specimens may be required by the purchaser or LR. Transverse properties for plates and wide flats are to be guaranteed by the supplier.~~ Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate ~~or shipping statement~~ are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. ~~The~~ As a minimum, the chemical composition is to include the contents of any grain refining elements used and of the residual elements.

■ *Section 4*
Steels for boilers and pressure vessels

4.2 Manufacture and chemical composition

4.2.2 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

4.4 Mechanical tests

4.4.7 Where plate is supplied from coil, the tensile tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

Existing paragraphs 4.4.7 *and* 4.4.8 *are to be renumbered* 4.4.8 *and* 4.4.9.

4.6 Certification of materials

4.6.1 ~~Each~~ At least two copies of each test certificate ~~or shipping statement is~~ are to be provided. They are to be of the type and to give the information detailed in 1.11 ~~together with general details of any heat treatment. The chemical~~ and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the content of ~~all the elements detailed in~~ any grain refining elements used and of the residual elements, as detailed in Table 3.4.1.

■ *Section 5*
Steels for machinery fabrications

5.2 Certification of materials

5.2.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements.

■ *Section 6*
Ferritic steels for low temperature service

6.2 Manufacture and chemical composition

6.2.4 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

6.4 Mechanical tests

6.4.9 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

6.6 Certification of materials

6.6.1 ~~Each~~ At least two copies of each test certificate ~~or shipping statement is to~~ are to be provided. They are to be of the type and give the information detailed in 1.11 together with general details of the heat treatment. ~~The chemical composition is to include the content of all the elements~~ As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Tables 3.3.2 or 3.6.1.

■ *Section 7*
Austenitic and duplex stainless steels

7.9 Certification of materials

7.9.1 ~~Each test certificate or shipping statement is to give the information detailed in 1.11, together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. The chemical composition is to include the content of all the elements detailed in Table 3.7.1.~~ At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, where applicable, the results obtained from intercrystalline corrosion tests, and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements, as detailed in Table 3.7.1.

■ *Section 8*
Plates with specified through thickness properties

8.5 Non-destructive examination

8.5.1 All ‘Z’ grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with and in compliance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.7 Certification of materials

8.7.2 Steel grade requirements are to comply with Sections 1 to 7.

■ *Section 9*
Bars for welded chain cables

9.10 Certification of materials

9.10.1 Each consignment of bars is to be accompanied by a certificate of a type and in accordance with 1.11 but with the addition of the grade of chain cable.

■ *Section 10*
High strength quenched and tempered steels for welded structures

10.5 Certification of materials

10.5.1 At least two copies of each test certificate ~~or shipping statement~~ are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, ~~The~~ chemical composition is to include the contents of ~~all the~~ any grain refining elements used and of the residual elements as detailed in Table 3.10.1.

Chapter 4
Steel Castings

Effective date 1 July 2010

■ *Section 1*
General requirements

1.7 Visual and non-destructive examination

1.7.1 This Section gives the general requirements for non-destructive examination of steel castings. As an alternative, castings may be examined in accordance with a National Specification, provided it gives reasonable equivalence to these Rules.

Existing paragraphs 1.7.1 *to* 1.7.3 *are to be renumbered* 1.7.2 *to* 1.7.4.

~~1.7.4~~ 1.7.5 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or dye penetrant inspection (for austenitic stainless steel castings, *see* Section 8) in accordance with ~~1.7.8~~ 1.7.9, unless more specific requirements for non-destructive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

~~1.7.5~~ 1.7.6 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be ~~carried out by competent operators using reliable and efficiently maintained equipment. The testing procedures are to be acceptable to the Surveyor~~ in accordance with the requirements of Ch 1,5.

~~1.7.6~~ 1.7.7 The manufacturer is to provide the Surveyor with a signed ~~statement~~ report confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects. ~~Brief details of the testing procedure used are also to be included in this statement.~~

~~1.7.7~~ 1.7.8 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable for the final inspection. Prods are not permitted on finished machined surfaces. ~~Where current flow methods are used for magnetisation, particular care is to be taken to avoid damaging finished machined surfaces by contact burns from the prods.~~

~~1.7.8~~ 1.7.9 Where required, magnetic particle or ~~liquid~~ dye penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:

(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm from the edge.
(d) In way of welds.
(e) In way of chaplets.
~~(d)~~(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

~~Acceptance standards are to be to the satisfaction of the Surveyor.~~

~~1.7.9~~ 1.7.10 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations for a distance not less than 50 mm from the edge.
~~(d)~~(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g. bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
~~(c)~~(f) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.

~~1.7.10~~ 1.7.11 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in ~~1.7.9~~ 1.7.10. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

~~1.7.11~~ 1.7.12 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7.13 The general acceptance criteria given in 2.5.2 are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.9 Rectification and dressing of ~~defective~~ castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive ~~testing~~ examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or ~~liquid~~ dye penetrant testing. ~~Small surface irregularities sealed by welding are to be treated as weld repairs.~~

1.9.5 A statement and/or sketch detailing the extent and position of all welds ~~repairs~~ is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 ~~Where it has been agreed that the casting can be repaired, the work~~ All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where ~~the weld repair of defects~~ welding is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out ~~weld repairs~~ welding unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the ~~weld repairs~~ welds.

1.9.10 Welding is to be ~~done~~ carried out under cover, in positions free from draughts and adverse weather conditions~~,~~ ~~by qualified welders with adequate supervision~~. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.13 Special consideration may be given to a local stress relieving heat treatment where both the ~~repaired~~ welded area is small and machining of the casting has reached an advanced stage but prior agreement is to be obtained from LR in writing ~~(Materials and NDE Department)~~. The welding procedure is to be such that residual stresses are minimised.

1.9.14 On completion of heat treatment, ~~the weld repairs~~ all welds and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive ~~testing~~ examination used. The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, Tables 13.2.4 to 13.2.6 in Chapter 13, as appropriate.

1.9.15 Where no ~~weld repairs have to be~~ welding has been made on a casting, the manufacturer is to provide the Surveyor with a written statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of ~~repairs~~ all welds made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10 Identification of castings

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) Manufacturer’s name or trade mark.
~~(b)~~(c) LR or Lloyd’s Register and the abbreviated name of LR’s local office.
~~(c)~~(d) Personal stamp of Surveyor responsible for inspection.
~~(d)~~(e) Test pressure, where applicable.
~~(e)~~(f) Date of final inspection.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

~~1.11.1~~ 1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser’s name and order number.
(b) Description of castings and steel ~~quality~~ grade.
(c) Identification number.
(d) Steel making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

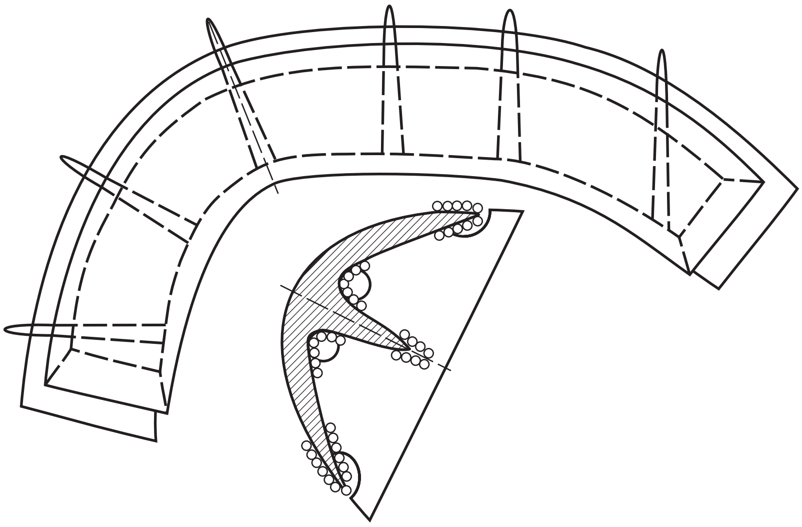
~~1.11.2~~ 1.11.3 Where applicable, the manufacturer is to provide a signed ~~statement~~ report regarding non-destructive ~~testing~~ examination as required by ~~1.7.6~~ 1.7.7 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

Chapter 4

Section 2
Castings for ship and other structural applications

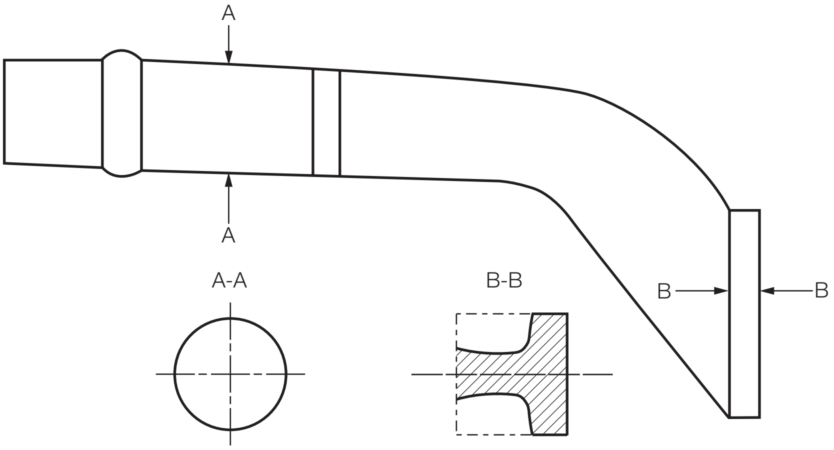
2.5 Non-destructive examination

2.5.2 The extent and methods of non-destructive examination to be applied to typical hull steel castings are shown in Figs. 4.2.1 to 4.2.6 in addition to the areas specified in 1.7.9 and 1.7.10.



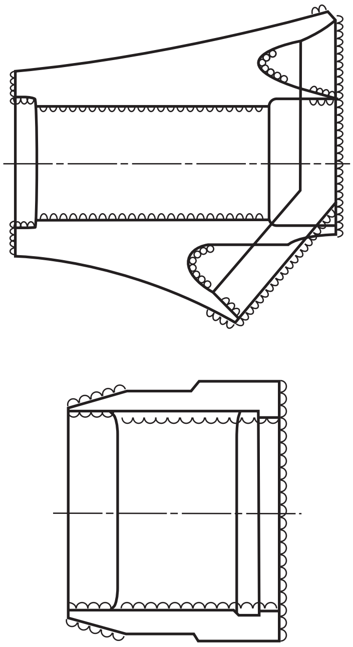
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing

Fig. 4.2.1 **Extent of non-destructive evaluation for stern frame castings**



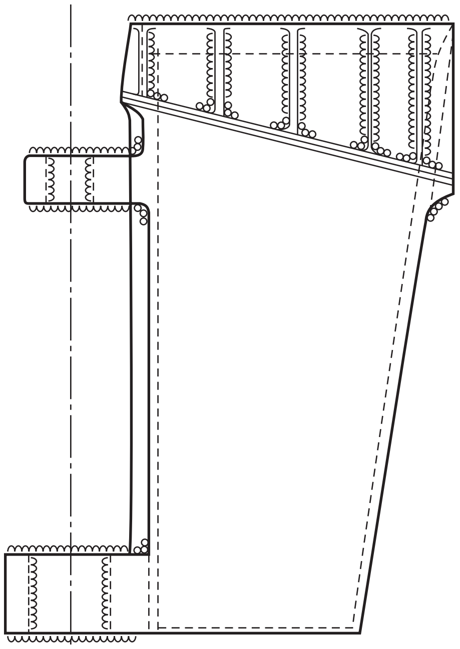
Location of non-destructive examination
All surfaces: Visual examination
Magnetic particle and ultrasonic testing

Fig. 4.2.2 **Extent of non-destructive evaluation for rudder stock castings**



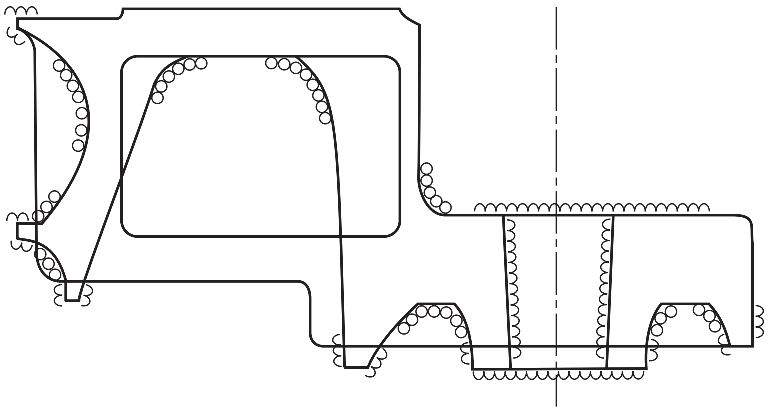
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

Fig. 4.2.3
Extent of non-destructive evaluation for stern boss castings



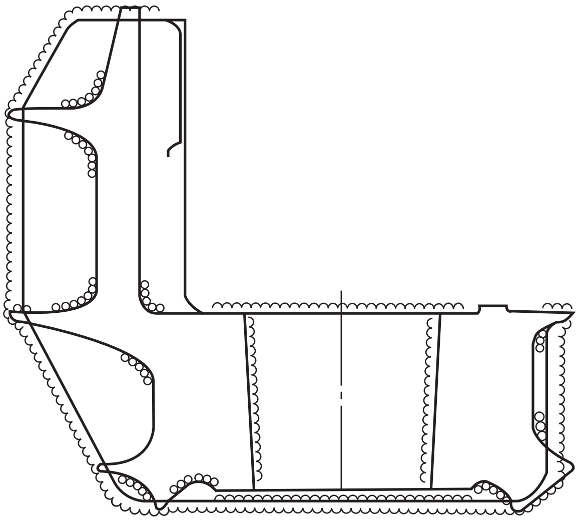
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (OOO): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

Fig. 4.2.4
Extent of non-destructive evaluation for rudder hanging castings



Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (OOO): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌒⌒⌒): Ultrasonic testing

Fig. 4.2.5 Extent of non-destructive evaluation for rudder (upper part) castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌣⌣⌣): Ultrasonic testing

Fig. 4.2.6
Extent of non-destructive evaluation for rudder (lower part) castings

2.5.3 Acceptance levels for Visual Inspection are to be taken as follows:

(a) No cracks or hot tears are permitted.
(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.
(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by 2.6.

2.6 Acceptance levels for surface crack detection

2.6.1 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Non-linear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or dye penetrant testing (PT) are;

(a) Level MT1/PT1 – fabrication weld preparation areas.
(b) Level MT2/PT2 – other locations indicated on Figs. 4.2.1 to 4.2.6.

The acceptance criteria are shown in Table 4.2.2. Cracks and hot tears are not acceptable.

2.6.4 Acceptance criteria for ultrasonic testing are shown in Table 4.2.3 as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks or hot tears are not acceptable.

2.6.5 Level UT1 is applicable to the following:

(a) Fabrication weld preparations for a distance of 50 mm.
(b) 50 mm depth from the final machined surface including boltholes.
(c) Fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end.
(d) Castings subject to cyclic bending stresses, e.g. rudder horn, rudder castings and rudder stocks, the outer one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm^2
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4, *see* Note 1 4, *see* Note 1 4, *see* Note 1	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-Linear Linear Aligned	10 6 6	7 5 5

NOTES
1. Minimum of 30 mm between relevant indications.
2. In weld repairs, the maximum dimension is 2 mm.

Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings

Quality level	Allowable disc shape according to the Distance-Gain Size (DGS), mm	Maximum number of indications to be registered, *see* Note 1	Allowable length of linear indications, mm, *see* Note 2
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0

NOTES
1. Grouped in an area measuring 300 x 300 mm.
2. Measured on the scanning surface.

2.6.6 Level UT2 is applicable to the following:

(a) For locations which are not specified in 2.6.5, nominated for ultrasonic testing in Figs. 4.2.1 to 4.2.6 or on the inspection plan.

(b) Positions outside locations nominated for level UT1 examination where feeders and gates have been removed.

(c) Castings subject to cyclic bending stresses, at the central one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

2.6.7 Ultrasonic acceptance criteria for casting areas not nominated in Figs. 4.2.1 to 4.2.6 will be subject to special consideration based on the anticipated stress levels and the type, size and position of the discontinuity.

2.6.8 Parts which are welded are to be examined by the same method as at the initial inspection as well as by additional methods as required by the Surveyor.

■ *Section 4*
Castings for crankshafts

4.7 Rectification of defective castings

~~*4.7.3* Welded repairs are to be undertaken only when the repairs are considered to be necessary and are approved by the Surveyor.~~

~~*4.7.4*~~ *4.7.3* Subject to prior agreement and submission of the detailed welding procedure for approval by LR, ~~weld repairs~~ welding may be carried out prior to the final austenitising heat treatment.

(Part only shown)

~~*4.7.5*~~ *4.7.4* Approval for ~~weld repairs~~ welding will not be given in the following circumstances:

(Part only shown)

~~*4.7.6*~~ *4.7.5* Provided that the Surveyors are satisfied that ~~repairs by~~ welding ~~are~~ is justified, they may also authorise welding ~~repairs~~ to the surfaces of crankwebs, following the final austenitising heat treatment, within the following limits:

(c) Larger welds ~~repairs~~ on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

(*Part only shown*)

~~*4.7.7*~~ *4.7.6* Subsequent to the final austenitising heat treatment, ~~weld repairs~~ welding may ~~also~~ be authorised in the surface of the bore for the journal (or pin) within the following limits:

Existing paragraphs 4.7.8 *and* 4.7.9 *are to be renumbered* 4.7.7 *and* 4.7.8.

~~*4.7.10*~~ *4.7.9* ~~Weld repairs are~~ Welding is to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

~~*4.7.11*~~ *4.7.10* All castings are to be given a preliminary refining heat treatment prior to the commencement of ~~weld repairs~~ welding. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is charged to the furnace for post-weld heat treatment.

~~*4.7.12*~~ *4.7.11* Where ~~weld repairs are~~ welding is carried out after the final austenitising heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600ºC, *see also* 1.5.2.

~~*4.7.13*~~ *4.7.12* Welds are to be dressed smooth by grinding~~, and proven by magnetic particle and, where appropriate, ultrasonic inspection~~. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see* 1.9.15 and 1.9.14 ~~free from harmful defects~~.

■ *Section 5*
Castings for propellers

5.4 Mechanical tests

5.4.5 Separately cast test bars may be used subject to prior approval of the Surveyor. Test bars must be cast from the same heat, or heats, and must also be heat treated with castings they represent.

5.5 Non-destructive examination

5.5.3 Castings are to be free from cracks and hot tears.

5.6 Rectification of defective castings

5.6.10 All welds are to be inspected by the appropriate NDE method, *see* 1.7.

5.8 Certification of materials

5.8.1 ~~The~~ In addition to the requirements in Ch 4,1.11, the manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

~~(a) Purchaser's name and order number.~~
~~(b)~~(a) Description of casting with drawing number.
~~(c) Type of steel, including designation and chemical composition.~~
~~(d)~~(b) Diameter, number of blades, pitch, direction of turning.
~~(e) Cast identification number.~~
~~(f) Details of heat treatment, where applicable.~~
~~(g)~~(c) Skew angle, if in excess of 25°.
~~(h)~~(d) Final mass.
~~(j) Results of mechanical tests.~~
~~(k)~~(e) Vessel identification, where known.

■ *Section 9*
Steel castings for container corner fittings

9.8 Certification of materials

9.8.1 For each consignment ~~the manufacturer~~ a manufacturer's certificate is to be issued (*see* Ch 1,3.1), ~~is to provide the Surveyor with a certificate or delivery note~~ containing at least the following:

(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.

Chapter 5
Steel Forgings

Effective date 1 July 2010

■ *Section 1*
General requirements

1.4 Chemical composition

~~*1.4.4* Details of the proposed chemical composition for carbon-manganese steel forgings intended for welding and alloy steel forgings are to be submitted for approval.~~

1.7 Mechanical tests

(Part only shown)

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or ~~30~~ 80 mm, whichever is less, below any heat treated surface;

1.8 Visual and non-destructive examination

1.8.3 ~~Visual examination may indicate areas which are to be examined by magnetic particle, dye penetrant or ultrasonic examination in addition to that indicated in 1.8.4.~~ All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, dye penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. ~~All such tests are to be carried out by competent operators using reliable and efficiently maintained equipment. The testing procedures used are to be agreed with the Surveyors.~~ All tests are to be carried out in accordance with the requirements of Ch 1,5.

1.8.5 Magnetic particle and ~~liquid~~ dye penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5.~~ Where current flow methods are used for magnetisation, particular care is to be taken to avoid damaging machined surfaces by contact burns from the prods.~~ For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

1.8.6 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Nonlinear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

~~*1.8.6*~~ *1.8.7* Acceptance standards for defects found by ~~magnetic particle or liquid penetrant testing are to be to the satisfaction of the Surveyors and~~ visual or non destructive examinations are to be in accordance with any specific requirements of the approved plan, and with any additional requirements of this Chapter. In all cases they are to be to the satisfaction of the Surveyor.

Existing paragraphs 1.8.7 *and* 1.8.8 *are to be renumbered* 1.8.8 *and* 1.8.9.

~~*1.8.9*~~ *1.8.10* In the circumstance detailed in either ~~1.8.7 or 1.8.8~~ 1.8.8 or 1.8.9, the manufacturer is to provide the Surveyor with a signed ~~statement~~ report confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects. ~~Brief details of the testing procedure used are also to be included in this statement.~~

Existing paragraphs 1.8.10 *to* 1.8.12 *are to be renumbered* 1.8.11 *to* 1.8.13.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination (as appropriate to the material). At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for ~~the approval of~~ review by the Surveyors prior to the commencement of the proposed rectification. A ~~statement~~ report and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Repair welding is not permitted for crankshafts or similar rotating components.

Existing paragraphs 1.9.3 *and* 1.9.4 *are to be renumbered* 1.9.4 *and* 1.9.5*.*

1.9.6 Non-open indications evaluated as segregation are acceptable.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

Existing paragraph 1.11.1 *is to be renumbered* 1.11.2*.*

~~*1.11.2*~~ *1.11.3* ~~The~~ As a minimum, the chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

~~*1.11.3*~~ *1.11.4* Where applicable, the manufacturer is also to provide a signed ~~statement~~ report regarding ultrasonic examination as required by ~~1.8.7~~ 1.8.8, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

Existing paragraph 1.11.4 *is to be renumbered* 1.11.5*.*

Section 2
Forgings for ship and other structural applications

2.5 Non-destructive examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or dye penetrant testing where appropriate).

2.5.2 Surface inspections are to be carried out in the zones I and II as indicated in Fig. 5.2.1.

2.5.3 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm^2. The area is to be taken in the most unfavourable location relative to the indication being evaluated.

2.5.4 The allowable number and size of indications in the reference area is given in Table 5.2.2.

Table 5.2.2 Steel forgings surface inspection

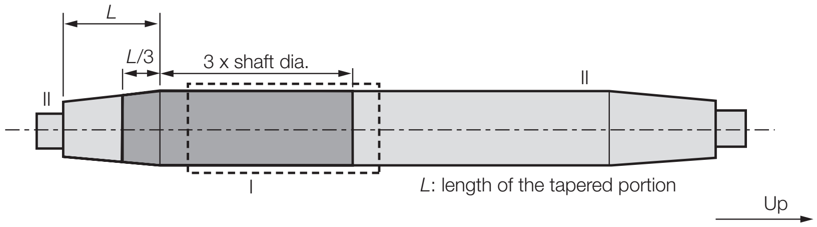
Inspection zone	Maximum number of indications	Type of indication	Maximum number each type	Maximum dimension, mm
I	3	Linear Non-linear Aligned	0, *see* Note 3 0, *see* Note	— 3,0 —
II	10	Linear Non-linear Aligned	3, *see* Note 7 3, *see* Note	3,0 5,0 3,0

NOTE
Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts and cylinder cover bolts.

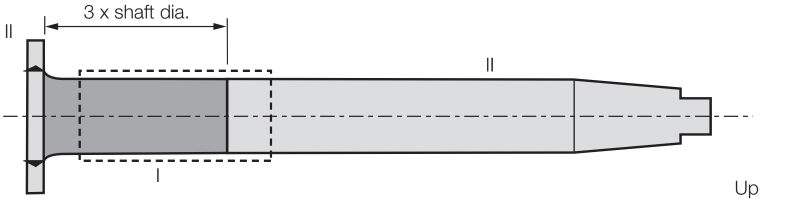
2.5.5 Volumetric inspection is to be carried out by ultrasonic testing using the contact method.

2.5.6 Ultrasonic testing is to be carried out on rudder stocks having a finished diameter of 200 mm or greater.

2.5.7 Ultrasonic testing is to be carried out in the zones I to III as indicated in Fig. 5.2.2. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

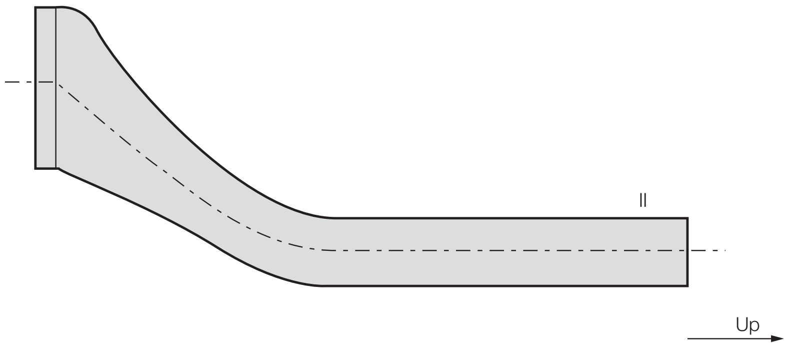


(a) Type A



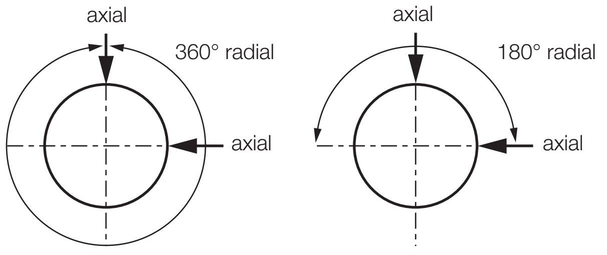
NOTE
Welded areas are to be treated as Zone I

(b) Type B



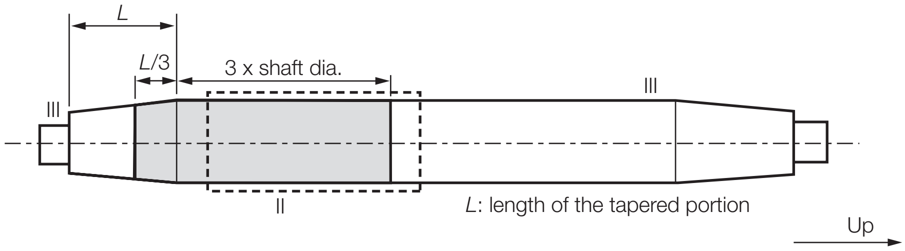
(c) Type C

Fig. 5.2.1 Inspection zones for magnetic particle/dye penetrant testing on rudder stocks

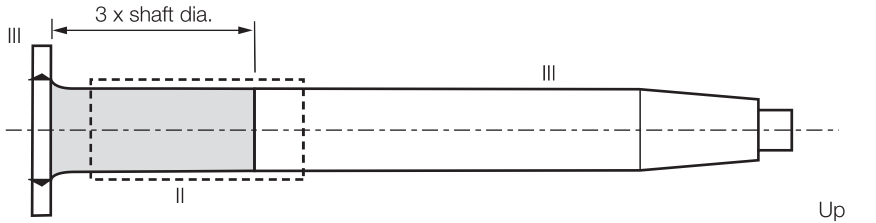


Zone II
Zone III

Scanning direction for Type A and Type B

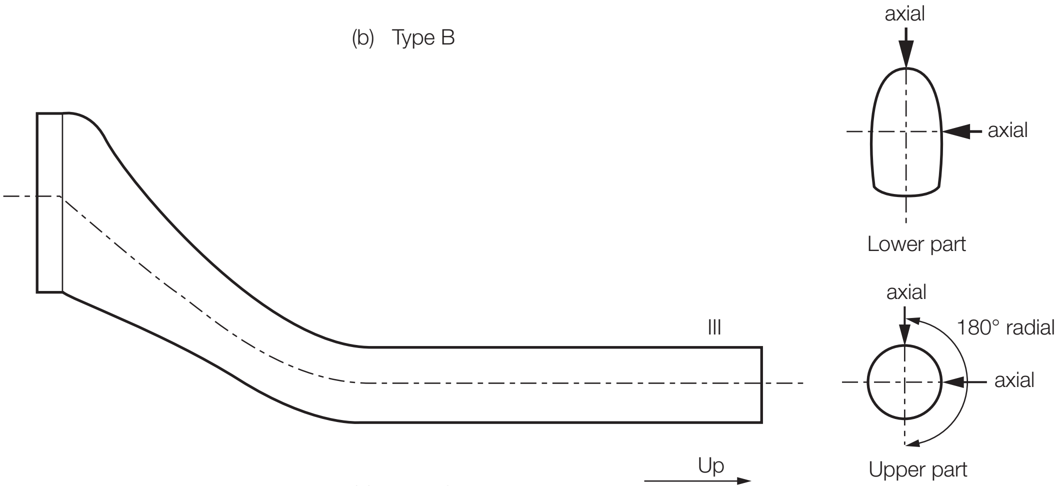


(a) Type A



NOTE
Special consideration is given to the welded areas

(b) Type B



(c) Type C

Scanning direction
for Type C

Fig. 5.2.2 Inspection zones for ultrasonic testing on rudder stocks

■ *Section 3*
Forgings for shafting and machinery

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than 100 mm), on all connecting rod, piston rod, and crosshead forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
    - Cylinder covers
    - Crossheads
    - Main bearings
    - Connecting rod bearings~~.~~
    - Propeller blade fastening bolts
    - Crankpin bolts
    - Tie rod bolts
    - Additionally, bolts for engine bore diameters of less than 400 mm but having a minimum diameter 50 mm or greater (which are subjected to dynamic stress), are also to be subjected to surface examinations.

3.5.2 The areas to be tested by magnetic particle or dye penetrant testing are ~~those where experience shows defects are most likely to occur, and are to be mutually agreed between the Surveyor and the manufacturer~~ shown in Fig. 5.3.4 and Fig. 5.3.5. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested. ~~The test results are to be to the Surveyor's satisfaction.~~

3.5.3 Surface inspection acceptance criteria are to be in accordance with 2.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

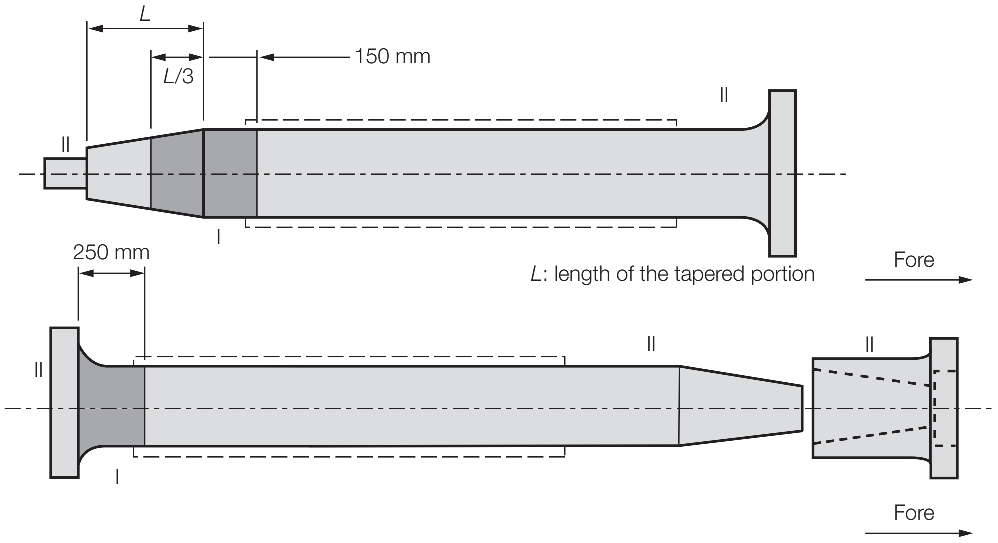
~~*3.5.3*~~ *3.5.4* Ultrasonic testing is to be carried out in accordance with 2.5 on the following items:

(a) Shafts having a finished diameter of ~~250~~ 200 mm or larger when intended for main propulsion or other essential services.

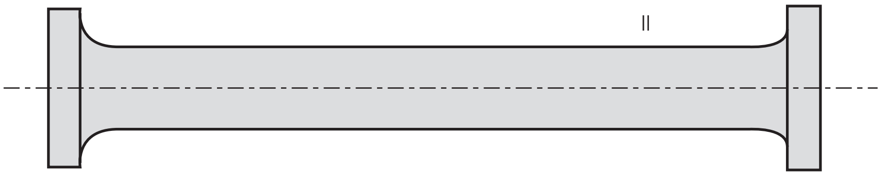
(b) All piston crowns and cylinder covers.

(c) Piston rods, ~~and~~ connecting rods and crossheads for engines having a bore diameter greater than ~~400~~ 200 mm.

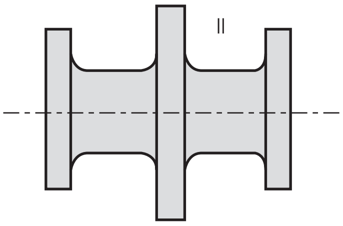
~~The test results are to be to the Surveyor's satisfaction.~~ The areas to be tested are shown in Fig. 5.3.6 and Fig. 5.3.7. Areas of other components not shown in these drawings are to be agreed with the Surveyor.



(a) Propeller shaft



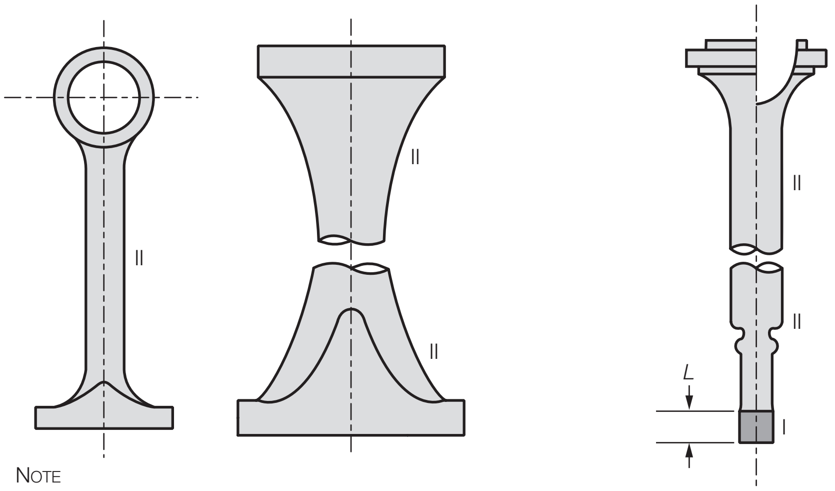
(b) Intermediate shaft



(c) Thrust shaft

NOTE
For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 5.3.4 Zones for magnetic particle/dye penetrant testing on machinery components

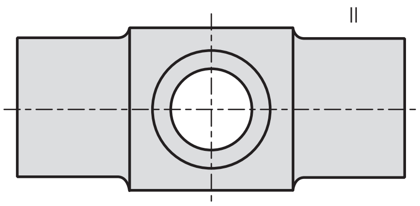


NOTE
Thread, holes and their circumstances are to be treated as Zone I

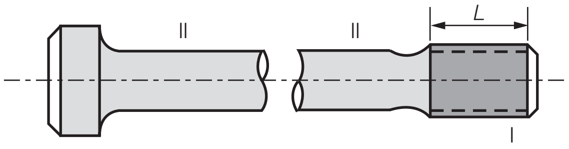
L: Length of thread

(a) Connecting rod

(b) Piston rod



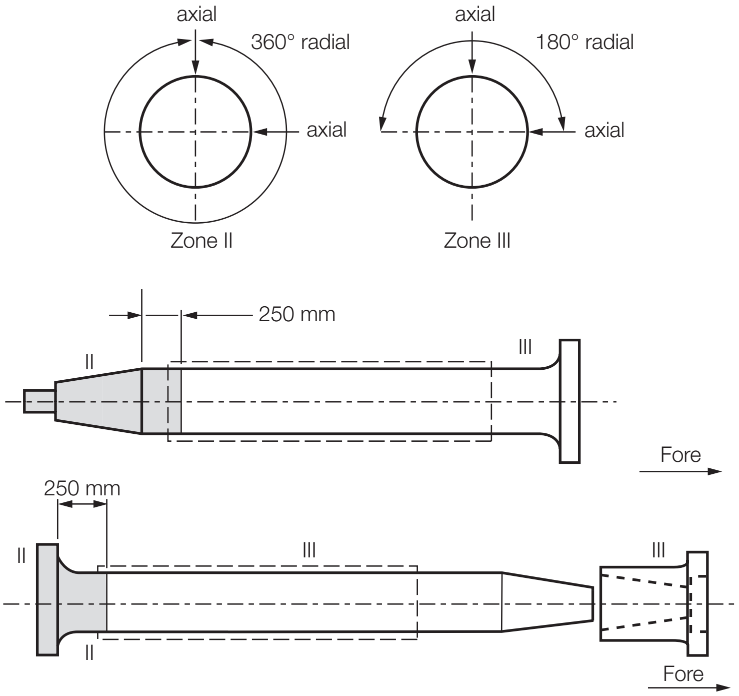
(c) Cross head



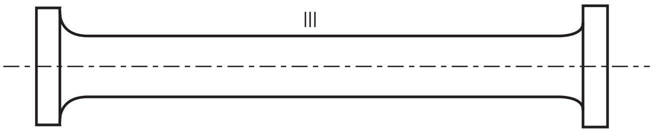
L: Length of thread

(d) Bolt

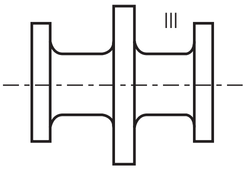
Fig. 5.3.5 Zones for magnetic particle/dye penetrant testing on machinery components



(a) Propeller shaft



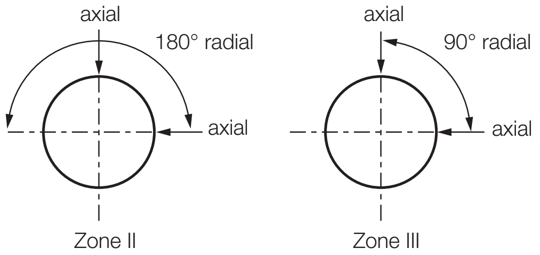
(b) Intermediate shaft



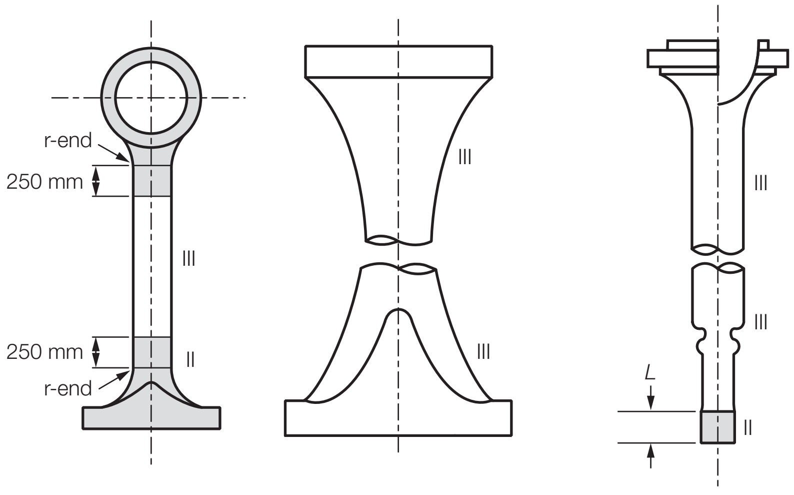
(c) Thrust shaft

NOTES
1. For hollow shafts, 360° radial scanning applies to Zone III
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II

Fig. 5.3.6 Zones for ultrasonic testing on shafts



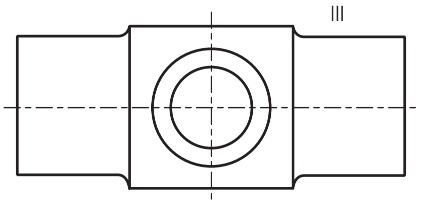
Scanning direction



L: length of thread

(a) Connecting rod

(b) Piston rod



(c) Cross head

Fig. 5.3.7 Zones for ultrasonic testing on machinery components

3.5.5 Ultrasonic acceptance criteria are shown in Table 5.3.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

Table 5.3.4 Acceptance criteria for ultrasonic testing

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), *see* Note 1, mm	Allowable length of indication, mm	Allowable distance between two indications, *see* Note 2, mm
Propeller shaft Intermediate shaft	II	Outer $d \leq 2$ Inner $d \leq 4$	≤10 ≤15	≥20 ≥20
Thrust shaft Rudder stock	III	Outer $d \leq 3$ Inner $d \leq 6$	≤10 ≤15	≥20 ≥20
Connecting rod Piston rod Crosshead	II	$d \leq 2$	≤10	≥20
	III	$d \leq 4$	≤10	≥20

NOTES
1. Outer part means the part beyond one third of the shaft radius from the centre. The inner part means the remaining core area.
2. For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication.

■ *Section 4*
Forgings for crankshafts

4.5 Mechanical tests

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests is ~~tests are~~ to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1). For continuous grain flow (CGF) crankshaft forgings, where sufficient material exists for a second longitudinal tes, the second set of tests may be taken in a tangential direction from the crankthrow (test position C in Fig. 5.4.2).

4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 and 2.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in Fig. 5.4.3.

4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in ~~1.8.7~~ 1.8.8 and 2.5, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks. The extent of ultrasonic testing is shown in Fig. 5.4.4.

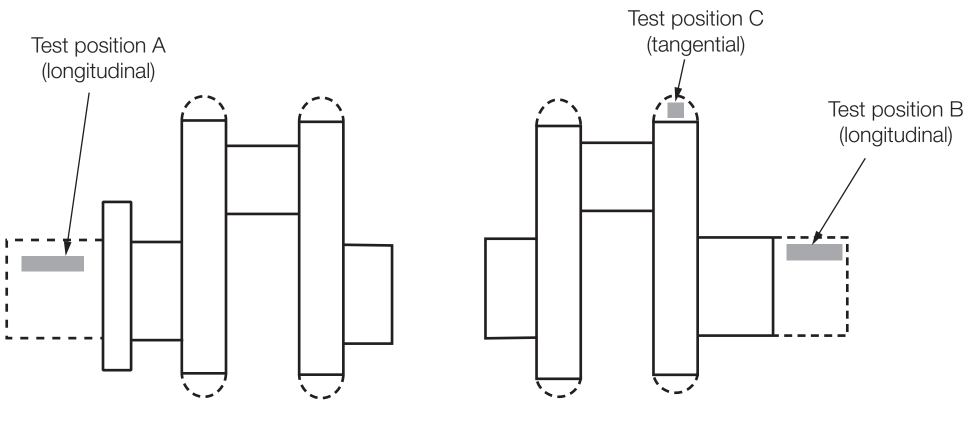
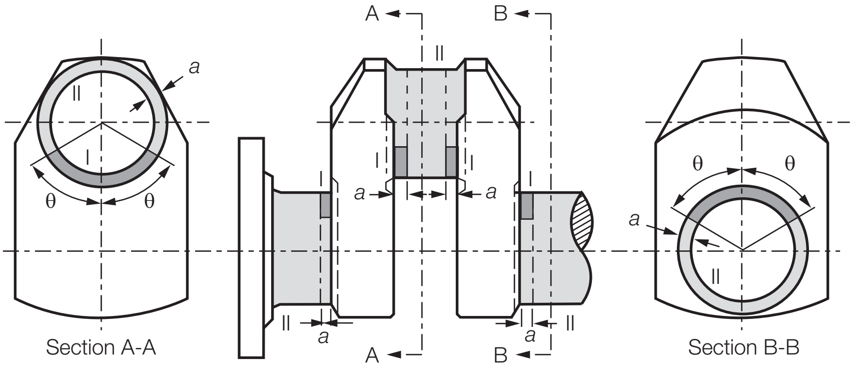
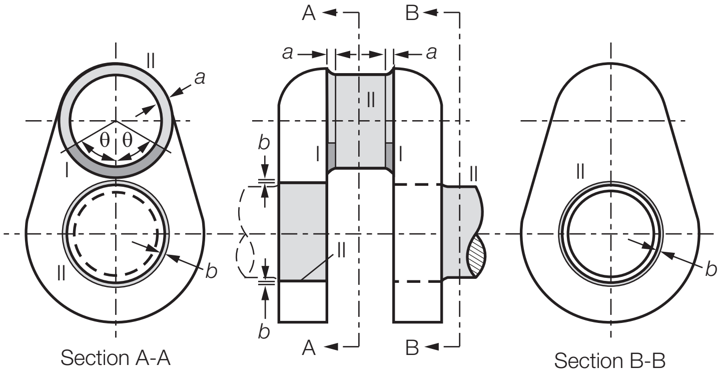


Fig. 5.4.2 CGF Crankshaft



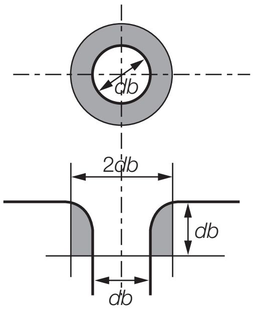
(a) Soild crankshaft



(b) Semi built-up crankshaft

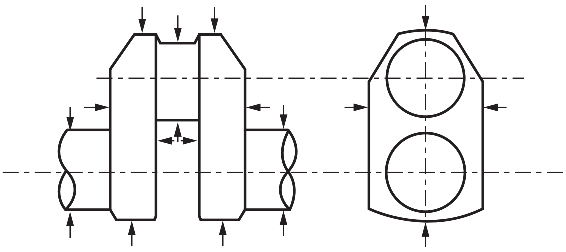
NOTES

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil are to be treated as Zone I, (*see* the figure on the right)
2. In the above figures:
   $\theta = 60^\circ$
   $a = 1{,}5r$
   $b = 0{,}05d$ (: circumferential surfaces of shrinkage fit)
   where
   r : fillet radius
   d : journal diameter
3. Identification of the Zones:
   ▓ : Zone I
   ░ : Zone II

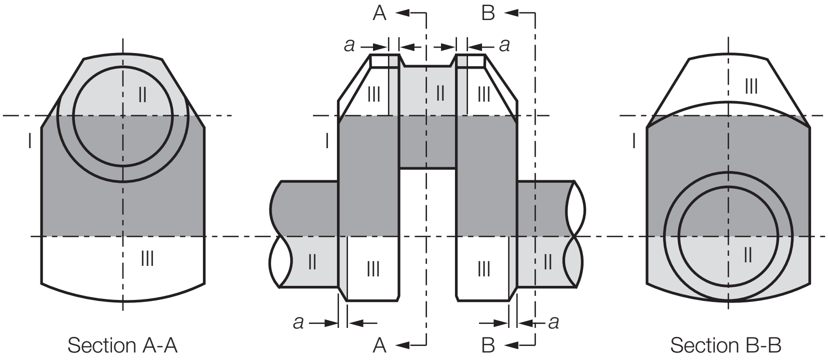


db: Oil hole bore diameter

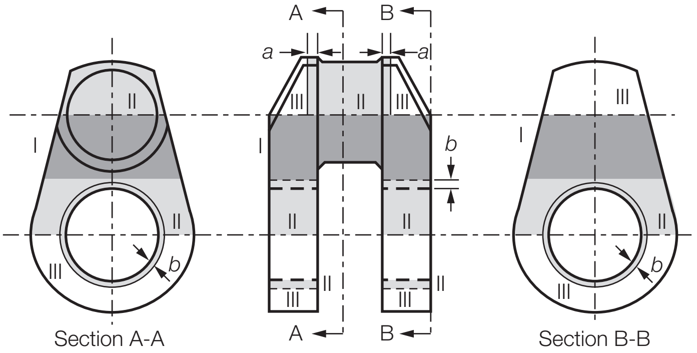
Fig. 5.4.3 Zones for magnetic particle/dye penetrant testing on crankshafts



Scanning direction



(a) Solid crankshaft



(b) Semi built-up crankshaft

NOTES

1. In the above figures:
   a = 0,1*d* or 25 mm, whichever is greater
   b = 0,05*d* or 25 mm, whichever is greater (: circumstances of shrinkage fit)
   where
   d : pin or journal diameter
2. The mid third area of crank pins and/or journals within a raduis of 0,25*d* between the webs may generally be coordinated to Zone II
3. Identification of the Zones:
   ▓ : Zone I
   ░ : Zone II
   □ : Zone III

Fig. 5.4.4 Zones for ultrasonic testing on crankshafts

4.6.3 Surface inspection acceptance criteria are to be in accordance with 2.5 and with Table 5.4.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

4.6.4 Ultrasonic acceptance criteria are shown in Table 5.4.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

Table 5.4.4 Surface inspection acceptance for crankshaft forgings – Allowable number and size of indications in a reference area of 225 cm^2

Inspection zone	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm
I Critical fillet area	0	Linear Non-linear Aligned	0 0 0	— — —
I I Important fillet area	3	Linear Non-linear Aligned	0 3 0	— 3,0 —
III Journal surfaces	3	Linear Non-linear Aligned	0 3 0	— 5,0 —

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), mm	Allowable length of indication, mm	Allowable distance between two indications, *see* Note, mm
Crank shaft	I II III	$d \leq 2{,}0$ $d \leq 3{,}0$ $d \leq 4{,}0$	— ≤10 ≤15	— ≥20 ≥20

NOTE
For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.

Chapter 6

Steel Pipes and Tubes

Effective date 1 July 2010

■ *Section 1*
General requirements

1.13 Certification of materials

1.13.1 ~~The manufacturer is to provide the Surveyor with copies of the test certificate or shipping statement for all material which has been accepted.~~ Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

(Part only shown)
1.13.2 ~~Each test certificate is to contain the following particulars~~ The manufacturer is to provide LR with the following information:

1.13.3 ~~The~~ As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

■ *Section 5*
Austenitic stainless steel pressure pipes

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in Ch 1,3.1 together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in Table 6.5.1.

Chapter 7
Iron Castings

Effective date 1 July 2010

■ *Section 1*
General requirements

1.5 Heat treatment

~~*1.5.3* Where spheroidal graphite iron castings are to be impact tested they should be suitably ferritised, *see* 3.3.2.~~

Existing paragraph 1.5.4 *is to be renumbered* 1.5.3.

1.6 Test material

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on test samples, the sample is not to be separated from the casting until after heat treatment.

1.9 Rectification of defective castings

1.9.3 Repairs by welding are not permitted on grey cast iron parts and generally not permitted for spheroidal or nodular graphite iron castings, but may be considered in special circumstances for spheroidal or nodular graphite iron castings. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

Existing paragraph 1.12.1 *is to be renumbered* 1.12.2.

1.12.3 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.8, together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.

■ *Section 2*
Grey iron castings

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 4), the specified tensile strength is to be not less than 200 N/mm^2 ~~and not more than 450 N/mm^2~~ subject to any additional requirements of the relevant Rules. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

■ *Section 3*
Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in ~~3.3.2~~ 3.4.2.

3.2 Heat treatment

3.2.1 The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test are to undergo a ferritising heat treatment, *see* 3.4.2.

Existing sub-Sections 3.2 *to* 3.4 *are to be renumbered* 3.3 *to* 3.5.

~~3.2~~ 3.3 Test material

~~3.2.1~~ 3.3.1 The test samples are to be as detailed in Figs. 7.3.1 ~~or~~, 7.3.2 or 7.3.3. The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

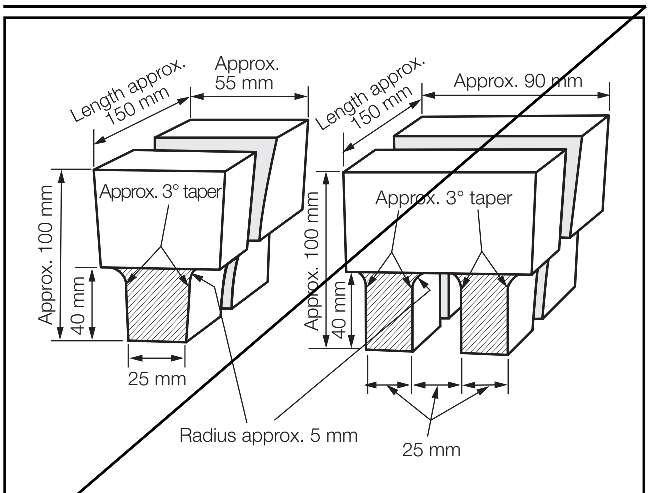


Fig. 7.3.1 U-type test samples

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u	25	12	50	75
v	55	40	90	125
x	40	30	60	65
y	100	80	150	165
Z	To suit testing machine			
Rs	Approximately 5			

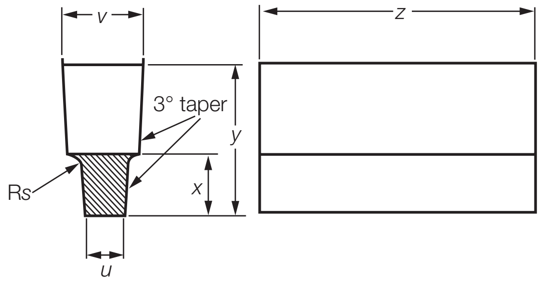
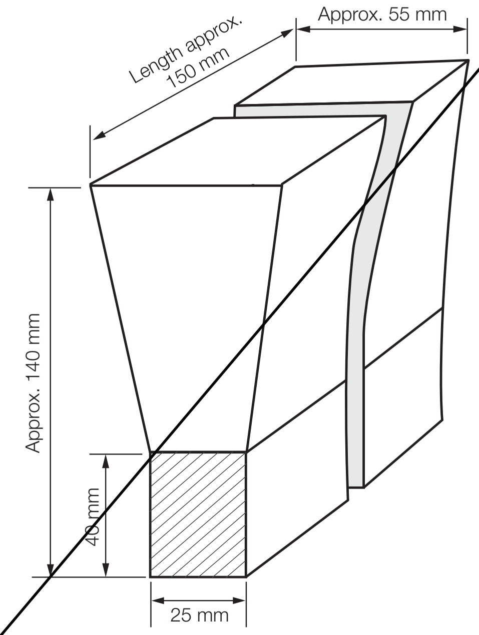


Fig. 7.3.1 Type A (U-type) test samples



~~**Fig. 7.3.2 Y-type test samples**~~

Dimension	Standard sample, mm
u	25
v	90
x	40
y	100
Z	To suit testing machine
Rs	Approximately 5

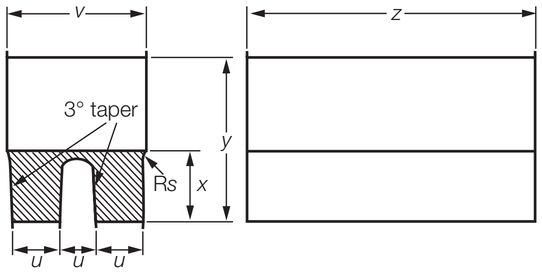


Fig. 7.3.2 Type B (Double U-type) test samples

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u	25	12	50	75
v	55	40	100	125
x	40	25	50	65
y	140	135	150	175
Z	To suit testing machine			
Minimum thickness of mould surrounding test sample	40	40	80	80

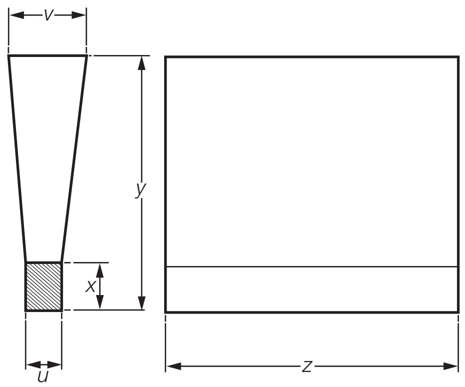


Fig. 7.3.3 Type C (Y-type) test samples

~~3.3~~ 3.4 Mechanical tests

3.4.3 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 7.3.1 and 7.3.2 but subject to any additional requirements of the relevant Rules.

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings
(*Part only shown*)

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_0}$ % minimum	Typical hardness value HB (*see* ~~3.3.1~~ 3.4.1)	Typical structure of matrix (*see* ~~3.4.1~~ 3.5.1)

NOTE
~~If required, intermediate values may be calculated by linear interpolation.~~ Proof stresses need only be determined if specifically requested.

Table 7.3.2 Mechanical properties: ~~impact tested grades~~ special qualities (*Part only shown*)

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*see* Note 1) N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ minimum % (*see* Note 2)	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*see* Note ~~2~~ 3)	Average energy J minimum (*see* Note 4)
350	220	22	110 – 170	20 –40	17 (14) 12 (10)
400	250	18	140 – 200	20 –20	14 (11) 12 (10)

NOTES
1. Proof stresses need only be determined if ~~included in the specification~~ specifically requested.
2. In the case of integrally cast samples, the acceptable elongation may be taken as 2 percentage points less.
~~2~~ 3. Tests need only be made at either of the temperatures listed, as appropriate.
4. The average value measured on three Charpy V-notch specimens. One of the three values may be below the specified minimum average value, but not less than the value shown in brackets.
5. Typical structure of the matrix is ferrite.

Section 4
Iron castings for crankshafts

4.7 Certification of materials

Chapter 8
Aluminium Alloys

Effective date 1 July 2010

Section 1
Plates, bars and sections

1.1 Scope

1.1.3 Plates and sections less than 3,0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

Existing paragraphs 1.1.3 *to* 1.1.5 *are to be renumbered* 1.1.4 *to* 1.1.6.

1.4 Dimensional tolerances

1.4.2 Under thickness tolerances for extruded products ~~for marine construction are given in Table 8.1.2~~ are to comply with an acceptable National or International Standard.

~~Table 8.1.2 Underthickness tolerances for~~ ~~extrusions for marine construction~~

Nominal thickness range, mm	Open profiles, sections circumscribed by a circle of diameter, mm			Closed profiles
	≤250	>250 ≤400	>400	
≥3,0 <6,0	0,25	0,35	0,40	0,25
≥6,0 <50	0,30	0,40	0,45	0,30

1.4.5 Verification of dimensions is the responsibility of the manufacturer. Acceptance by Surveyors of material which is later found to be defective does not absolve the manufacturer from this responsibility.

Table ~~8.1.3~~ 8.1.2 Chemical composition, percentage
(*Part only shown*)

Element	5083	5383
Copper	0,10 max.	~~0,10~~ 0,20 max.
Magnesium	4,0—4,9	4,0—~~4,9~~ 5,2
Silicon	0,40 max.	0,25 max.
Iron	0,40 max.	0,25 max.
Manganese	0,40—1,00	0,7—1,0
Zinc	0,25 max.	~~0,25~~ 0,40 max.
Chromium	0,05—0,25	~~0,05—0,25~~ 0,25 max.
Titanium	0,15 max.	0,15 max.
Zirconium		~~0,02~~ 0,20 max.
Other elements:		
each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.

Table 8.1.3 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on 4d, %	Elongation on $5{,}65\sqrt{S_o}$, %
5083-O	$3 \le t \le 50$	125	275–350	16	14
5083-H112	$3 \le t \le 50$	125	275	12	10
5083-H116	$3 \le t \le 50$	215	305	12 (*see* Note 1)	10
5083-H321	$3 \le t \le 50$	215–295	305–380	12	10
5086-O	$3 \le t \le 50$	100	240–305	16	14
5086-H112	$3 \le t \le 12{,}5$	125	250	8	—
	$12{,}5 < t \le 50$	105	240	—	9
5086-H116	$3 \le t \le 50$	195	275	10 (*see* Note 2)	9
5059-O	$3 \le t \le 50$	160	330	24	24
5059-H116	$3 \le t \le 20$	270	370	10	10
	$20 < t \le 50$	260	360	10	10
5059-H321	$3 \le t \le 20$	270	370	10	10
	$20 < t \le 50$	260	360	10	10
5383-O	$3 \le t \le 50$	145	290	16	17
5383-H116	$3 \le t \le 50$	220	305	10	10
5383-H321	$3 \le t \le 50$	220	305	10	10
5456-O	$3 \le t \le 6{,}3$	130–205	290–365	16	—
	$6{,}3 \le t \le 50$	125–205	285–360	16	14
5456-H116	$3 \le t \le 30$	230	315	10	10
	$30 < t \le 40$	215	305	—	10
	$40 < t \le 50$	200	285	—	10
5456-H321	$3 \le t \le 12{,}5$	230–315	315–405	12	—
	$12{,}5 \le t \le 40$	215–305	305–385	—	10
	$40 \le t \le 50$	200–295	285–370	—	10
5754-O	$3 \le t \le 50$	80	190–240	18	17

NOTES

1. 10% for thickness up to and including 12,5 mm.
2. 8% for thickness up to and including 6,3 mm.
3. For application to liquefied natural gas carriers or liquefied natural gas tankers where thicknesses are in excess of 50 mm, the mechanical properties given in this table are, in general, to be complied with.

1.5 Chemical composition

1.5.2 The chemical composition of these samples is to comply with the requirements of Table ~~8.1.3~~ 8.1.2.

1.7 Test material

~~Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloys~~

Alloy and temper condition	Thickness, *t*, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m, N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ %	Elongation on 5*d* %
5083-0/H111	≤12,5	125	275-350	16	
	>12,5	125	275-350		15
5083–H112	≤12,5	125	275	12	
	>12,5	125	275		10
5083–H116	≤12,5	215	305	12 (*see* Note 1)	
	>12,5	215	305		10
5083–H321	≤12,5	215-295	305-380	10 (*see* Note 2)	
	>12,5	215-295	305-380		9
5383–0/H111	3 ≤ *t* ≤ 50	145	290		17
5383–H116 or H321	3 ≤ *t* ≤ 50	220	305		10
5086–0/H111	≤12,5	100	240-310	17	
	>12,5	100	240-310		16
5086–H112	≤12,5	125	250	8	
	>12,5	105	240		9
5086–H116	≤12,5	195	275	10	
	>12,5	195	275		9
5086–H321	≤12,5	185	275-335	10	
	>12,5	185	275-335		9
5059–0/H111	3 ≤ *t* ≤ 50	160	330		24
5059–H116 or H321	3 ≤ *t* ≤ 50	270 (*see* Note 3)	370 (*see* Note 3)		10
5456–0	≤12,5	130-205	290-365	16	
	>12,5	125-205	285-360		14
5456–H116	≤12,5	230	315	10	
	>12,5	200	290		10
5456–H321	≤12,5	230-315	315-405	12	
	>12,5	215-305	305-385		10
5754–0/H111	≤12,5	80	190	18	
	>12,5	80	190		17
6061–T5/T6		240	290		10
6082–T5/T6		240	280		8

NOTES
1. 10% for thickness up to and including 6,0 mm.
2. 8% for thickness up to and including 6,0 mm.
3. Yield strength minimum 260 N/mm^2 and tensile strength minimum 360 N/mm^2 for thickness exceeding 20 mm.

1.8 Mechanical tests

1.8.3 The results of all tensile tests are to comply with the values given in ~~Tables 8.1.4 to 8.1.6~~ Table 8.1.4, as applicable.

~~Table 8.1.5 Minimum mechanical properties for~~ acceptance purposes of selected open profile extruded aluminium alloys

Alloy and temper condition	0,2% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on 5,65 S_o %
6005A–T5/T6	215	260	6
6061–T5/T6	240	260	8
6082–T5/T6	260	310	8

NOTE
Values cover thicknesses up to and including 50 mm; thickness ~~above 50 mm will be subject to special consideration.~~

~~Table 8.1.6 Minimum mechanical properties for~~ acceptance purposes of selected closed profile extruded aluminium alloys

Alloy and temper condition	0,2% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ %
6005A–T5/T6	215	250	5
6061–T5/T6	205	245	4
6082–T5/T6	240	290	5

NOTE
Values cover thicknesses up to and including 50 mm; thickness ~~above 50 mm will be subject to special consideration.~~

Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected extruded aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on 4d, %	Elongation on 5,65 $\sqrt{S_o}$, %
5083-O	$3 \leq t \leq 50$	110	270–350	14	12
5083-H111	$3 \leq t \leq 50$	165	275	12	10
5083-H112	$3 \leq t \leq 50$	110	270	12	10
5086-O	$3 \leq t \leq 50$	95	240–315	14	12
5086-H111	$3 \leq t \leq 50$	145	250	12	10
5086-H112	$3 \leq t \leq 50$	95	240	12	10
5059-H112	$3 \leq t \leq 50$	200	330	—	10
5383-O	$3 \leq t \leq 50$	145	290	17	17
5383-H111	$3 \leq t \leq 50$	145	290	17	17
5383-H112	$3 \leq t \leq 50$	190	310	—	13
6005A-T5	$3 \leq t \leq 50$	215	260	9	8
6005A-T6	$3 \leq t \leq 10$	215	260	8	6
	$10 < t \leq 50$	200	250	8	6
6061-T6	$3 \leq t \leq 50$	240	260	10	8
6082-T5	$3 \leq t \leq 50$	230	270	8	6
6082-T6	$3 \leq t \leq 5$	250	290	6	—
	$5 < t \leq 50$	260	310	10	8

NOTE
The values are applicable for longitudinal and transverse tensile test specimens as well.

1.9 Corrosion tests

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67. Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production practices are not to be changed after approval of the reference micrographs. ~~For batch acceptance of 5000 series alloys in the H116 and H321 tempers for use in direct contact with seawater, metallographic examination of one sample selected from mid width at one end of a randomly selected plate is to be carried out. The microstructure of the sample is to be compared to an approved reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary networks of aluminium-magnesium precipitate in excess of the approved reference photomicrographs, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards.~~

1.10 Pressure weld tests

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends after final heat treatment.

1.14 Certification of materials

1.14.1 ~~The manufacturer's test certificate can be accepted provided it has been stamped and endorsed by the Surveyor.~~ A manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

(Part only shown)
1.14.2 Each test certificate ~~or shipping statement~~ is to include the following particulars:

(j) Details of temper condition and heat treatment, where applicable.

■ *Section 2*
Aluminium alloy rivets

2.8 Certification of materials

(*Part only shown*)
2.8.1 ~~The test certificate~~ A manufacturer's certificate is to be issued (*see* Ch 1,3.1) and for each consignment of manufactured rivets is to include the following particulars:

■ *Section 3*
Aluminium alloy castings

3.11 Certification of materials

(Part only shown)
3.11.1 ~~The manufacturer is to provide the Surveyor with a written statement~~ A LR certificate is to be issued (*see* Ch 1,3.1) giving the following particulars for each casting or batch of castings which have been accepted:

■ *Section 4*
Aluminium/steel transition joints

4.6 Certification of materials

(Part only shown)
4.6.1 ~~Each test certificate or shipping statement is to~~ A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and as a minimum is to include the following particulars:

Chapter 9

Copper Alloys

Effective date 1 July 2010

■ *Section 1*
Castings for propellers

1.12 Certification of materials

1.12.1 A LR certificate is to be issued for each propeller, *see* Ch 1,3.1.

(Part only shown)
~~*1.12.1*~~ *1.12.2* The manufacturer is to provide the Surveyor with ~~a written statement giving~~ the following particulars for each casting:

■ *Section 2*
Castings for valves, liners and bushes

2.12 Certification of materials

2.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

(*Part only shown*)
~~*2.12.1*~~ *2.12.2* The manufacturer is to provide the Surveyor with ~~a written statement giving~~ the following particulars for each casting or batch of castings which has been accepted:

Existing paragraph 2.12.2 *is to be renumbered* 2.12.3.

■ *Section 3*
Tubes

3.13 Certification of materials

~~*3.13.1* The manufacturer is to provide the Surveyor with copies of the test certificate or shipping statement for all material which has been accepted.~~

(Part only shown)
~~*3.13.2*~~ *3.13.1* ~~Each test certificate is to contain the following particulars~~ A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1), giving the following particulars for each casting or batch of castings which has been accepted:

Chapter 11

Approval of Welding Consumables

Effective date 1 July 2010

■ *Section 1*
General

1.2 Grading

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades
(Part only shown)

Consumable grade	Suitable for steel grades (*see* Notes)			
2Y40	*AH32*	*AH36*	*AH40*	–
2Y40	*DH32*	*DH36*	*DH40*	–
3Y40	*EH32*	*EH36*	*EH40*	–
4Y40	*FH32*	*FH36*	*FH40*	–
5Y40	*FH32*	*FH36*	*FH40*	–

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. ~~For upgrading and uprating, tests from butt weld assemblies will be required in addition to the normal annual approval tests.~~ For upgrading in connection with impact properties, and uprating in connection with tensile properties, tests from butt weld assemblies will be required in addition to the normal annual approval tests. For upgrading in connection with hydrogen testing, specific tests will be required in accordance with ISO 3690. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

Section 3
Electrodes for manual and gravity welding

3.1 General

~~*3.1.10* Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in 3.5 welded in the horizontal-vertical position.~~

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes *(Part only shown)*

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to ~~4Y40~~ 5Y40	H15
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
$1\frac{1}{2}$ Ni	H15
$3\frac{1}{2}$ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

3.2 Deposited metal test assemblies

Table 11.3.2 Requirements for deposited metal tests (covered electrodes) (*Part only shown*)

Grade (*see* Note 3)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2 (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
5Y40	400	510 – 690	22	–60	47
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69

3.3 Butt weld test assemblies

Table 11.3.3 Requirements for butt weld tests (covered electrodes) (*Part only shown*)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Note 1) J minimum
				All positions (*see* Note 2)
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69

3.3.3 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 5Y40 electrodes	AH40, DH40, EH40 or FH40

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4. Where ISO 3690 is used as the testing method, three test specimens are to be prepared and tested, and all three hydrogen test results must be below the maximum value for the hydrogen mark required.

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.3. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested. Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in subsequent paragraphs of this sub-Section welded in the horizontal-vertical position.

■ *Section 4*
Wire-flux combinations for submerged-arc automatic welding

4.1 General

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations (*Part only shown*)

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to ~~4Y40~~ 5Y40	H15	NR
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
$1^1/2$ Ni	H15	NR
$3^1/2$ Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

4.3 Deposited metal test assemblies (multi-run technique)

Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations) (*Part only shown*)

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note) J minimum
5Y40	400	510 – 690	22	–60	39
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69

4.4 Butt weld test assemblies (multi-run technique)

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40
Grade 3Y40 wire-flux combinations	AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations	AH40, DH40, EH40 or FH40
Grade 5Y40 wire-flux combinations	AH40, DH40, EH40 or FH40

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.5 Approval tests for two-run technique

4.5.2 ~~Each pair of~~ Two welded assemblies ~~is~~ are to be made from a pair of plates of ~~two~~ matching thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

4.6 Butt weld test assemblies (two-run technique)

4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly, except as detailed in 4.6.8. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

■ *Section 5*

Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.5 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position. In all other cases, approval in the horizontal-vertical position will require a butt weld to be made in that position and be fully tested.

5.3 Approval tests for multi-run automatic welding

5.3.6 At the discretion of LR, wires approved for semi-automatic welding in the downhand position may also be approved without additional tests, for use in multi-run automatic welding.

Table 11.4.3 Requirements for butt weld tests (wire-flux combinations) (*Part only shown*)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69

Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations (*Part only shown*)

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to ~~4Y40~~ 5Y40	H15	~~NR~~ H15	~~H15~~ NR
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^{1}/_{2}$ Ni	H15	H15	NR
$3^{1}/_{2}$ Ni	H15	H15	NR
5 Ni	NR (*see* Note 3)	NR	NR
9 Ni	NR (*see* Note 3)	NR	NR

■ *Section 6*

Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.3 Superscript numbers are applied to the 'Y' of higher strength steel consumables, e.g. 2Y^1, to indicate the type of parent steel for which approval is applicable as follows:

Y^1 approval Grade for higher strength steel is limited to parent steel which has been treated only with aluminium.

Y^2 approval Grade for higher strength steel is appropriate to niobium-treated steels, whether aluminium treated or not. It also covers steels treated only with aluminium.

Existing paragraph 6.1.3 *is to be renumbered* 6.1.4.

6.2 Butt weld test assemblies

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:

(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) ~~One macro-section.~~ Two macro-sections.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.3 Annual tests

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:

(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) ~~One set of three Charpy V-notch impact tests with the specimens notched at the centre of the weld (position (1) in Fig. 11.6.2).~~ Two sets of three Charpy V-notch impact tests; one set with the notch at the centre of the weld (Position (1) in Fig. 11.6.2), and one set with the notch in the weld metal 2 mm from the fusion line (Position (2) in Fig.11.6.2).
(e) Chemical analysis.
(f) One macro-section.

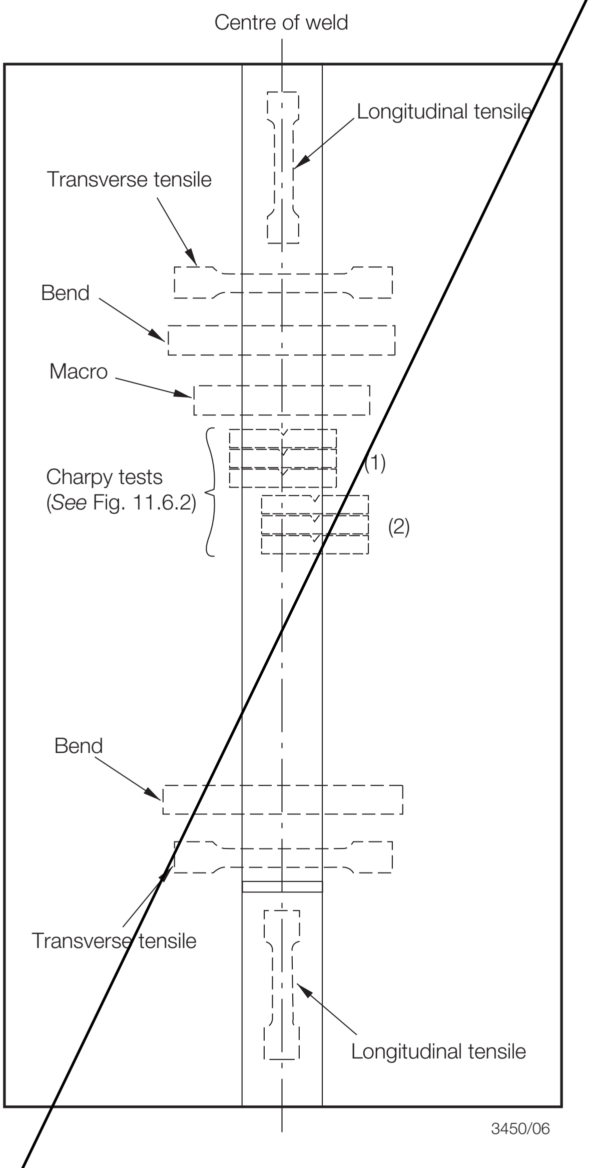


Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

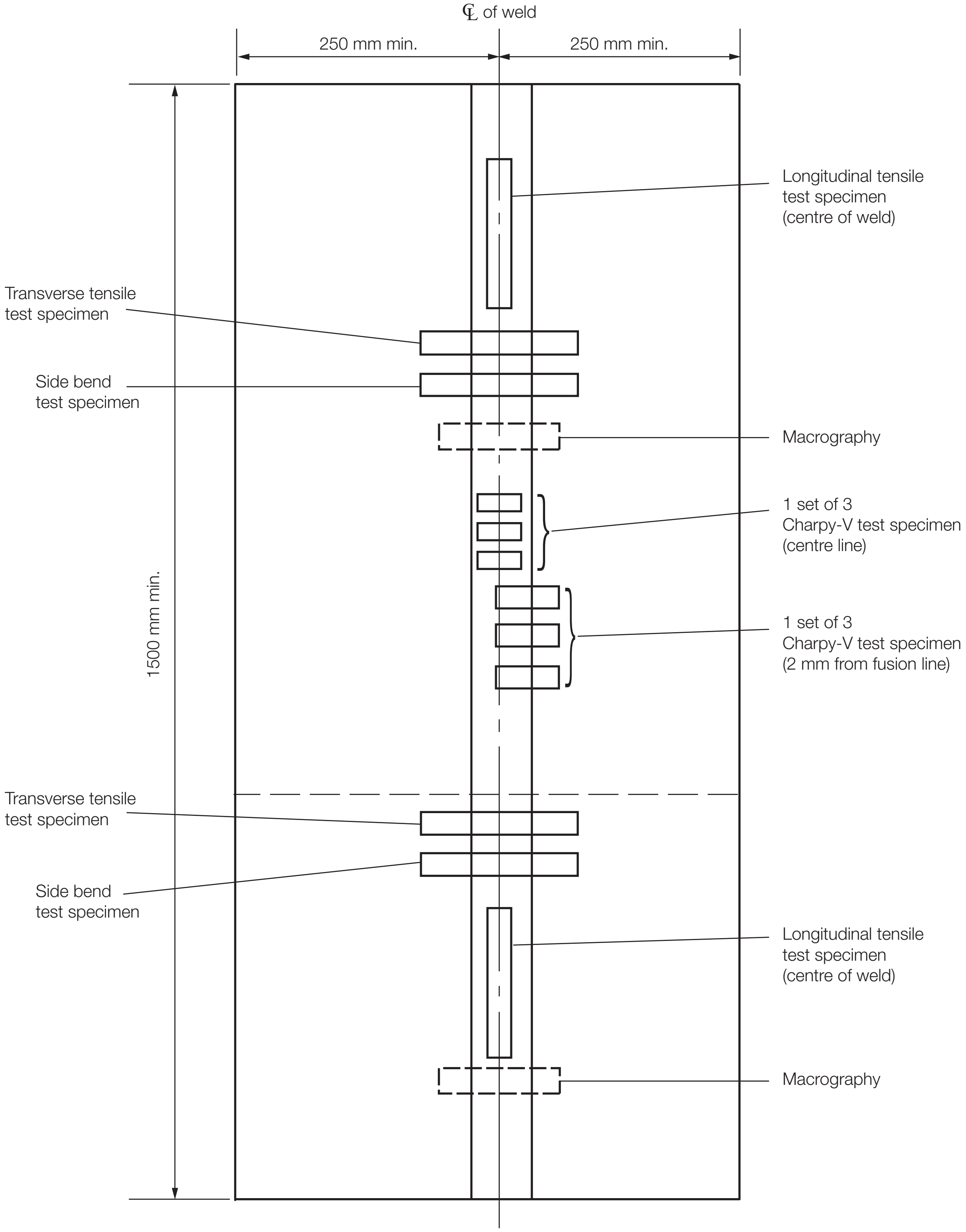

℄ of weld
250 mm min.
250 mm min.
1500 mm min.
Longitudinal tensile test specimen (centre of weld)
Transverse tensile test specimen
Side bend test specimen
Macrography
1 set of 3 Charpy-V test specimen (centre line)
1 set of 3 Charpy-V test specimen (2 mm from fusion line)
Transverse tensile test specimen
Side bend test specimen
Longitudinal tensile test specimen (centre of weld)
Macrography

Fig. 11.6.1 Butt weld test assembly for electro-slag or electro-gas welding

Section 7
Consumables for use in one-side welding with temporary backing materials

7.1 General

Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material
(Part only shown)

Approval grades
1 (1N), 2 (2N), 3 (3N)
1Y, 2Y, 3Y, 4Y
2Y40 to ~~4Y40~~ 5Y40
3Y42 to 5Y42
3Y46 to 5Y46
3Y50 to 5Y50
3Y55 to 5Y55
3Y62 to 5Y62
3Y69 to 5Y69
$1\frac{1}{2}$ Ni
$3\frac{1}{2}$ Ni
5 Ni (*see* Note 3)
9 Ni (*see* Note 3)

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.3 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):

(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens, one with the face in tension, the other with the root in tension.
(d) One macrosection.
(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a). ~~The bend specimens are to be tested, one with the face in tension, the other with the root in tension.~~

7.2.7 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the ~~uppermost~~ upper and ~~lowest~~ lower Charpy specimens of the downhand butt weld. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.3 Approval tests for high heat input automatic (A) techniques

7.3.7 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the ~~thinner~~ thicker plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

Section 8
Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by ‘SS/CMn’ and ‘Dup/CMn’ respectively, however, no buttering of test assembly plates is allowed for these two approvals.

Section 9
Consumables for welding aluminium alloys

9.1 General

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1. Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies, and may be of any temper listed in LR Rules.

9.5 Fillet weld test assembly

9.5.1 ~~One~~ When approval is being sought for both butt and fillet welding, one assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 When approval is being sought for fillet welding only, one assembly is to be prepared and welded in each position for which approval is sought, and tested as detailed in 9.5.1.

Existing paragraph 9.5.2 *is to be renumbered* 9.5.3.

Chapter 12
Welding Qualifications

Effective date 1 July 2010

■ *Section 2*
Welding Procedure Qualification Tests for Steels

2.3 Steel test assemblies

Table 12.2.1 Equivalent designations of welding positions *(Part only shown)*

Weld position		Standard	
		ISO 6947	AWS
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF PG	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G

2.5 Non-destructive examination (NDE)

2.5.5 All NDE ~~is to be performed in accordance with procedures acceptable to LR~~ is to be carried out in accordance with the requirements of Ch 1,5. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply.

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality (in accordance with 2.5.5) are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.11 Destructive tests for weld cladding of steel

2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, ~~on a surface parallel to the weld surface~~ on the final weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.

2.12 Mechanical test acceptance criteria for steels

2.12.6 **Hardness surveys**: The maximum hardness value reported is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤ 420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2. ~~For example, impact tests would be taken from the highest heat input position and hardness tests would be taken from the lowest heat input position.~~

2.13 Failure to meet requirements (Retests)

■ *Section 4*
Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

Table 12.4.3 Welding procedure approval, welding positions for aluminium alloys

Test position		Positions approved
Downhand	D	D
Horizontal-vertical	X	D, X~~, Vu~~
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O

NOTE
Welding in vertical down (Vd) position is not recommended.

Table 12.2.2 Impact test requirements for butt joints ($t \leq 50$ mm) *see* Notes 1 and 2 (*Part only shown*)

Grade of steel	Test temperature (°C) *see* Note 4	Value of minimum energy absorbed (J), *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	

NOTES
1. For thickness above 50 mm, impact test requirements are to be specially agreed.
2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.
4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

4.2 Requirements for copper alloys

Table 12.4.9 Range of approval for copper alloy material grades (*Part only shown*)

Category	Alloy grade used in the qualification test	Alloy grades approved
Tupes/pipes *see* Note 2	~~Copper-Phosphorus non arsenical~~ Copper-Phosphorus deoxidised - arsenical Copper-Phosphorus deoxidised - non arsenical Aluminium-brass	~~Copper-Phosphorus non arsenical~~ Copper-Phosphorus deoxidised - arsenical Copper-Phosphorus deoxidised - non arsenical Aluminium-brass

■ *Section 5*

Welder qualification tests

5.3 Examination and testing

Table 12.5.1 Welder qualification test requirements (*Part only shown*)

Examination type	Butt welds	Fillet welds	Pipe branch welds

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds ~~12~~ 8 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.

5.6 Range of approval

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \le 3$ $3 < t \le 12$ $t > 12$	t to $2t$ ~~3,0 to t~~ 3,0 to $2t$ $\ge 5,0$
Aluminium alloys	$t \le 6$ $6 < t \le 15$ $t > 40$ mm	0,7 to $2,5t$ $6,0 < t \le 40,0$ 41 to $2t$

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

5.6.8 A qualification test performed on plate confers approval to weld on pipes having an outside diameter greater than 500 mm in a fixed position (*see* Table 12.5.5 and Table 12.5.6).

Existing paragraphs 5.6.8 *to* 5.6.14 *are to be renumbered* 5.6.9 *to* 5.6.15.

~~Table 12.5.6 Welding position ranges for welder qualification~~

Test weld conditions		Positions qualified			
Type of weld	Test position	Plate, *see* Note 2		Pipe	
		Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt	D	D	D	D, *see* Note 1	D, *see* Note 1
	X	D, X	D, X	D, *see* Note 1	D, *see* Note 1
	Vu	D, Vu	D, X, Vu	D, *see*Note 1, Vu, *see* Note 1	D, *see* Note 1, Vu, *see* Note 1, X
	Vd	Vd	Vd	*See* Note 2	*See* Note 2
	O	D, X, Vu, O	D, X, Vu, O	D, *see* Note 1	D, X, Vu, O
Plate Fillet	D	—	D	—	D, *see* Note 1
	X	—	D, X	—	D, *see* Note 1, X
	Vu	—	D, X, Vu	—	D, *see* Note 1, X, Vu, *see* Note 1
	Vd	—	Vd	—	*See* Note 2
	O	—	D, X, Vu, O	—	D1, X, Vu, O
Pipe butt	D, *see* Note 1	D	D, X	D, *see* Note 1	D, *see*Note 1, X
	X	D, X	D, X	D, *see* Note 1, X	D, *see* Note 1, X
	D + Vu + O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, *see* Note 1	D, *see* Note 1, X, Vu, O
	D + Vd + O, *see* Note 3	Vd	Vd	D+Vu+O, *see* Note 3, Vd	Vd
	Axis at 45°, *see* Note 4,Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Note 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D, *see* Note 1	—	D	—	D, *see* Note 1
	X	—	D, X	—	D, *see* Note 1, X
	D + Vu + O, *see* Note 3	—	D, X, Vu, O	—	D, *see* Note 1, X, Vu, O
	D + Vd + O, *see* Note 3	—	Vd	D—	Vd

NOTES
1. Pipe rotate.
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests may be considered acceptable for pipes with diameter over 500 mm.

Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
Type of weld	Test position	Plate		Pipe, *see* Note 1	
		Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt, *see* Note 5	D	D	D	D	D
	X	D,X	D, X	D	D, X
	Vu	D, Vu	D, X, Vu	D	D, Vu
	Vd	Vd	Vd	—	—
	O	D, X, Vu, O	D, X, Vu, O	D	D, X, Vu, O
Plate Fillet, *see* Note 5	D	—	D	—	D
	X	—	D, X	—	D, X
	Vu	—	D, X, Vu	—	D, X, Vu
	Vd	—	Vd	—	—
	O	—	D, X, Vu, O	—	D, X, Vu, O
Pipe butt	D	D	D, X	D	D, X
	X	D, X	D, X	D, X	D, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, Vu, O	D, X, Vu, O
	D+Vd+O, *see* Notes 2 and 3	Vd	Vd	Vd	Vd
	Axis at 45°, *see* Note 4, Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Notes 2, 3 and 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D	—	D	—	D
	X	—	D, X	—	D, X
	D+Vu+O *see* Note 3	—	D, X, Vu, O	—	D, X, Vu, O
	D+Vd+O *see* Note 3	—	Vd	—	Vd

NOTES

1. Pipe D position means pipe in horizontal position and rotated, *see* Fig. 12.2.2(b) and Fig. 12.2.2(d).
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests confers approval to weld pipes with diameter greater than 500 mm.

Chapter 13

Requirements for Welded Construction

Effective date 1 July 2010

■ *Section 1*

General welding requirements

1.11 Non-destructive examination of welds

1.11.1 ~~Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to level III qualification of ISO 9712, SNT-TC-1A, EN473, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be approved by the Surveyor.~~ All procedures, and persons engaged in NDE, are to comply with the requirements of Ch 1, 5.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired and re-inspected.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter. The repairs are to be re-inspected using the same technique as the original inspection.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5. ~~Reports are to include the following information where appropriate:~~

~~(a) date of inspection;~~
~~(b) names, qualifications and signatures of operator and supervisor;~~
~~(c) component identification;~~
~~(d) weld identification, location and extent of testing;~~
~~(e) steel grade, type of joint, thickness of parent material, welding process;~~
~~(f) heat treatment status;~~
~~(g) test standard used;~~
~~(h) acceptance criteria;~~
~~(j) surface condition;~~
~~(k) inspection procedure reference;~~
~~(l) test equipment used;~~
~~(m) any test limitations, viewing conditions and temperature;~~
~~(n) statement of final acceptability to established criteria.~~

■ *Section 2*

Specific requirements for ship hull structure and machinery

2.2 Welding consumables

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements (*Part only shown*)

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steel – Low carbon	
304L (*see* Note 3)	304L
304LN (*see* Note 3)	304LN and 304L
316L	316L and 304L
316LN	316LN, 316L, 304LN and 304L
317L	317L, 316LN, 316L, 304LN and 304L
317LN	317LN, 317L, 316LN, 316L, 304LN and 304L

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.
3. These are LR Grades and do not correspond to any National or International Standards/Grades.

2.10 Post-weld heat treatment

(*Part only shown*)

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm, except where castings are directly welded to the hull structure.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks ~~and lack of fusion~~ and substantially free from lack of fusion, incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds is avoided.

Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length $t/2$ or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum t or 50 mm, whichever is less, *see* Note 3
Lack of root fusion	4013	Not accepted in butt joints welded from one side
Incomplete root penetration	4021	Not accepted in butt joint welded from one side
		Continuous maximum length $t/2$ or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length t or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length t or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum $2t$ or 100 mm, whichever is less, *see* Notes 3 and 4
Gas pore	2011	maximum dimension for a single pore: $d \leq 0{,}2t$, max. 4,0 mm *see* Note 5
Uniformly distributed porosity	2012	Maximum dimension of the area of imperfections: For single run welds: ≤ 1,5% For multi-run welds: ≤ 3% *see* Notes 6 and 7
Clustered (localised) porosity	2013	Maximum dimension of the summation of the projected area of the imperfection: ≤ 8% *see* Notes 6 and 7
Elongated cavity	2015	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *see* Notes 8 and 9
Wormholes	2016	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *see* Notes 8 and 9
Metallic inclusions other than copper	304	$h \leq 0{,}3t$, max. 3,0 mm *see* Note 8
Copper inclusions	3042	Not permitted

NOTES

1. t is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length ~~L1~~ l_d1 and ~~L2~~ l_d2 situated on a line and where the distance ~~L~~ l_d between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length ~~L1 + L + L2~~ $l_d1 + l_d + l_d2$.
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.
5. d is the diameter of the gas pore.
6. The limits for the maximum single gas pore within this group still apply.
7. Further reference to porosity limits may be obtained in ISO 5817:2007.
8. h is the width of the imperfection.
9. l is the length of the imperfection.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of ~~10 mm~~ 8 mm thickness or less. Ultrasonic testing is acceptable for welds of ~~10 mm~~ 8 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.8 Mechanical requirements

(Part only shown)
4.8.5 **Transverse bend test**. The bend test specimens are to be removed and tested in accordance with the following requirements:

(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).
(b) The specimen dimensions are to be in accordance with ~~Chapters 11 and 12~~ Chapter 2.

Table 13.4.1 Impact test requirements
(*Part only shown*)

Pressure vessel Class	Minimum design temperature
Class 1 *see* Note	–10°C or above
All Classes	Below –10°C
NOTE Impact testing is not required for Classes 2/1, 2/2 and 3.	

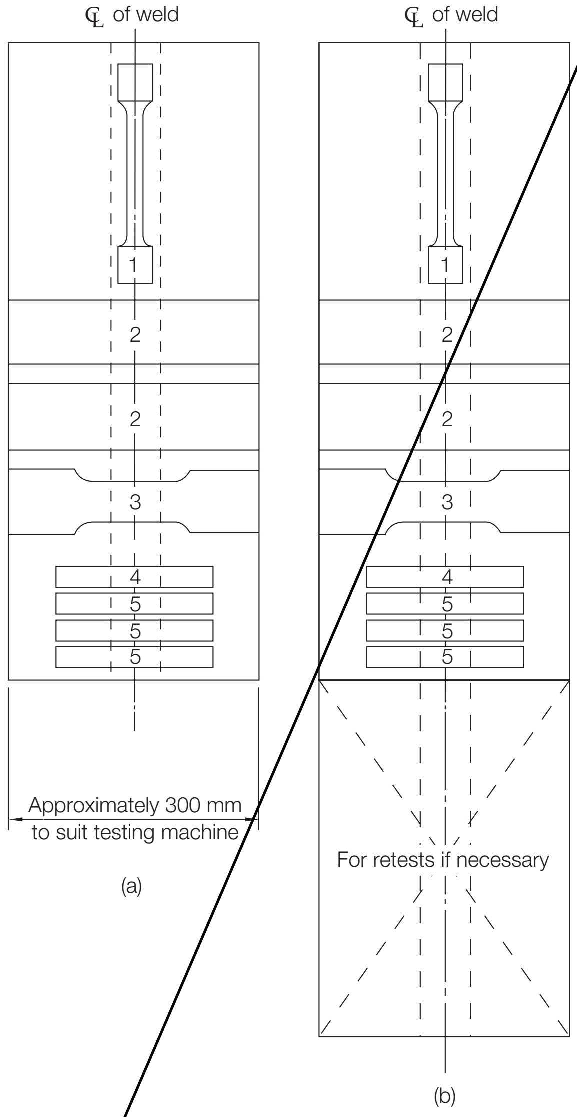
4.13 Extent of NDE for Class 1 pressure vessels

4.13.3 Full penetration tube sheet to shell welds are to be subjected to 10 per cent volumetric examination and 10 per cent surface inspection, prior to the installation of the tubes.

4.13.4 In addition to the acceptance limits stated in Tables 13.2.4 to 13.2.6, no cracks, lack of fusion, or lack of penetration is permitted.

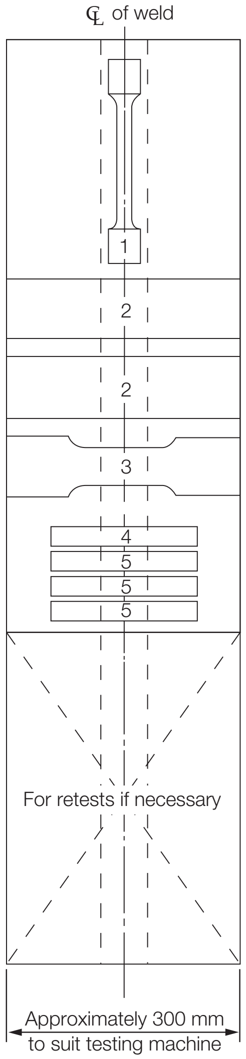
4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.4 The requirements of 4.13.3 and 4.13.4 apply to Class 2/1 pressure vessels.



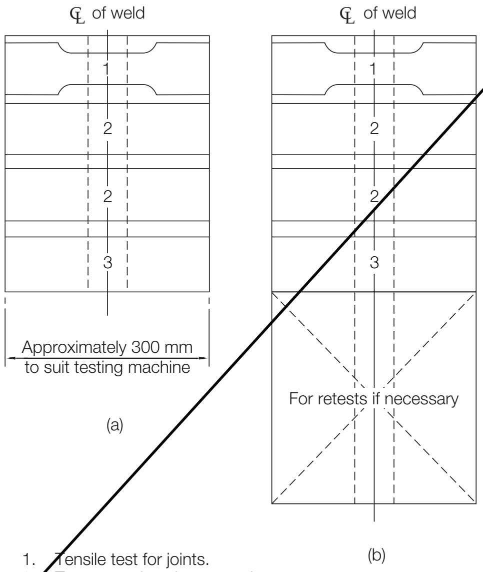
1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen and hardness test.
5. Charpy V-notch impact.
(For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1



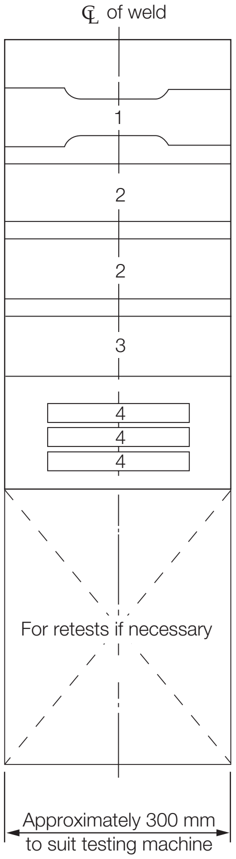
1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact.
   (For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1



~~1. Tensile test for joints.~~
~~2. Transverse bend test specimens.~~
~~3. Nicked bend test specimen.~~

~~**Fig. 13.4.2**~~
~~**Routine weld tests – Test specimens for Class 2/2 and Class 3**~~



1. Tensile test for joints.
2. Bend test specimens.
3. Nicked bend test specimen.
4. Charpy V-notch impact test specimens (if required by Table 13.4.1).

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5. ~~include the following information where appropriate:~~

~~(a) Date of inspection.~~
~~(b) Names, qualifications and signatures of operator and supervisor.~~
~~(c) Component identification.~~
~~(d) Weld identification, location and extent of testing.~~
~~(e) Steel grade, type of joint, thickness of parent material and welding process.~~
~~(f) Heat treatment status.~~
~~(g) Test standard used.~~
~~(h) Acceptance criteria.~~
~~(j) Surface condition.~~
~~(k) Inspection procedure reference.~~
~~(l) Test equipment used.~~
~~(m) Any test limitations, viewing conditions and temperature.~~
~~(n) Results showing size, position and nature of any defects repaired.~~
~~(o) Statement of final acceptability to established criteria.~~

■ *Section 5*
Specific requirements for pressure pipework

5.5 Non-destructive examination

5.5.3 ~~The extent of testing to be applied to butt welds or fillet welds in Class II pipes with an outside diameter greater or equal to 100 mm is at the Surveyor's discretion.~~ Butt welds in Class II pipes are to be subjected to at least 10 per cent random volumetric inspections when the outside diameter is greater than 100 mm.

5.5.4 NDE ~~is not required~~ for Class II pipes with a diameter less than 100 mm is to be at the discretion of the Surveyor.

5.5.6 Fillet welds on flange pipe connections of Class I pipes are to be examined by surface crack detection methods.

Chapter 14
Plastics Materials and other Non-Metallic Materials

Effective date 1 July 2010

■ *Section 1*
General requirements

1.1 Scope

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3 of this Chapter; and LR's *Materials and Qualification Procedures for Ships (MQPS), see* Ch 1,2.2.2.

■ *Section 2*
Tests on polymers, resins, reinforcements and associated materials

2.3 Thermosetting resins

2.3.5 Where resins which have been modified by the addition of waxes or polymers, for example 'low styrene emission or air inhibited' materials, it is to be confirmed that the use of such resins will not result in poor interlaminar adhesion when interruptions to the laminating process occur. The test procedure is to be as follows:

(a) A conventional room temperature curing catalyst/accelerator system is to be used with the resin for laminate preparation.
(b) A laminate of 25 to 35 per cent glass content in mass is to be prepared using two plies of 450 g/m^2 chopped strand mat. The laminate is to be prepared at ambient temperature (18° to 21°C). The laminate is to be allowed to stand for a minimum of four days but no longer than 6 days at ambient temperature.
(c) A further two plies of 450 g/m^2 chopped strand mat are to be laminated onto the exposed surface and cured at ambient temperature for 24 hours. The finished laminate is then to be post-cured at 40°C for 16 hours. The finished laminate is to have a glass content of 25 to 35 per cent.
(d) After cooling, the apparent interlaminar shear strength of the laminate is to be determined in accordance with ISO 14130; the minimum value is given in Table 14.5.5. Before testing the samples shall be conditioned at 23°C and relative humidity of 50 per cent for a period of 88 hours before testing.
(e) If the tests are undertaken at the resin manufacturer's own laboratory, the individual test values are to be reported and the broken test specimens retained for examination by LR.

Alternative test procedures will be considered with prior agreement.

■ *Section 3*

Testing procedures

3.7 Tests for specific materials

Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	~~ISO 527-2~~ ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	~~ISO 178~~ ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	~~ISO 62~~ ISO 62:2008	Method 1
Temperature of deflection under load	~~ISO 75-2~~ ISO 75-2:2004	Method A
Compressive properties	~~ISO 604~~ ISO 604:2002	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	~~ISO 527-2~~ ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	~~ISO 178~~ ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	~~ISO 62~~ ISO 62:2008	Method 1
Temperature of deflection under load	~~ISO 75-2~~ ISO 75-2:2004	Method A
Compressive properties	~~ISO 604~~ ISO 604:2002	Test speed = 1 mm/min

NOTES
1. ~~ISO 62~~ ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ~~ISO 62~~ ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ~~ISO 527-2~~ ISO 527-2:1993 – tensile properties are to be measured using extensometry.

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	~~ISO 527-4~~ ISO 527-4:1997	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	~~ISO 14125~~ ISO 14125:1998	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	~~ISO 604~~ ISO 604:2002	Test speed = 1 mm/min
Interlaminar shear	~~ISO 14130~~ ISO 14130:1997	
Water absorption	~~ISO 62~~ ISO 62:2008	Method 1
Glass content	~~ISO 1172~~ ISO 1172:1996	

NOTES
1. ~~ISO 62~~ ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ~~ISO 62~~ ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ~~ISO 527-4~~ ISO 527-4:1997 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

3.8 Structural core materials

(Part only shown)

3.8.1 Initially, the core shear strength and modulus are to be determined by ~~ISO 1922-1981~~ ISO 1922:2001 or ~~ASTM C273~~ ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ~~ASTM C393 (short beam)~~ ASTM C393/C393M:06 (short beam) at two representative thicknesses (i.e. 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	~~ISO 845-1977~~ ISO 845:2006
Tensile properties	~~ASTM C297-61~~ ASTM C297/C297M:04 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	~~ISO 844-1978~~ ISO 844:2007 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	~~ISO 1922-1981~~ ISO 1922:2001 Test speed = 1mm/min

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	~~ISO 180-1993 Unnotched~~ ISO 180-2000 Unnotched
Barcol hardness	~~EN 59~~ DIN EN59
Compressive strength	~~ISO 604~~ ISO 604:2002 Test speed = 1 mm/min
Water absorption	~~ISO 62 Method 1~~ ISO 62:2008 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	~~ISO 175~~ ISO 175:1999 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	~~ISO 752~~ ISO 75-2 Method A

■ *Section 5*
Control of material quality for composite construction

5.11 Minimum tested requirements for material approval

Table 14.5.2 Gel coat resins, minimum property values (*Part only shown*)

Properties	Minimum value
Water absorption	70 mg (max)
~~Specific gravity of cast resin~~	~~As measured~~

Table 14.5.3 Laminating resins, minimum property values (*Part only shown*)

Properties	Minimum value
Modulus of elasticity in tension	As measured
~~Flexural strength (stress at maximum load)~~	~~70 N/mm^2~~
~~Modulus of elasticity in flexure~~	~~As measured~~
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
~~Specific gravity of cast resin~~	~~As measured~~
NOTE These minimum values are for the recommended glass content by weight of 0,3.	

Table 14.5.5 Laminates, minimum property requirements (*Part only shown*)

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	~~$200G_c + 25$~~ $200G_c + 30$
	Modulus of elasticity in tension (kN/mm^2)	~~$15G_c + 2{,}0$~~ $15G_c + 2{,}4$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c - 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c - 0{,}5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 - 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 - 114G_c + 39$
Chopped strand mat	Flexural (stress at maximum load) (N/mm^2)	$502G_c^2 + 114{,}6$
	Modulus of elasticity in flexure (kN/mm^2)	$33{,}4G_c^2 + 2{,}7$

Section numbering in brackets reflects any Section renumbering necessitated by any of the Notices that update the current version of the Rules for Materials.

Chapter 3

1.10.3	*Reference* Ch 1,4.9 *now reads* Ch 1,4.8.

Chapter 4

4.3.1	*Reference* 4.7.5(c) *now reads* 4.7.4(c).
4.7.9 **(4.7.8)**	*Reference* 4.7.6 *now reads* 4.7.5. *Reference* 4.7.7 *now reads* 4.7.6.
6.5.1	*Reference* 1.7.6 to 1.7.10 *now reads* 1.7.7 to 1.7.11.
7.5.1	*Reference* 1.7.6 to 1.7.10 *now reads* 1.7.7 to 1.7.11.
8.6.1	*Reference* 1.7.6 to 1.7.10 *now reads* 1.7.7 to 1.7.11.
9.5.1	*Reference* 1.7.9 *now reads* 1.7.10. *Reference* 1.7.10 *now reads* 1.7.11.

Chapter 7

4.7.1	*Reference* 1.12.1 *now reads* 1.12.2.

Chapter 8

1.1.2	*Reference* 1.1.3 *now reads* 1.1.4.
1.8.3	*Reference* Tables 1.8.4 to 8.1.6 *now reads* Tables 1.8.3 to 8.1.6.

Chapter 9

2.12.2 **(2.12.3)**	*Reference* 2.12.1 *now reads* 2.12.2.

Chapter 10

2.11.2	*Reference* Pt 3, Ch 13,9.2 *now reads* Pt 3, Ch 13,10.2.
2.13.5	*Reference* 1.3.9 *now reads* 1.4.

Chapter 11

9.7.1	*Reference* Table 1.8.3 *now reads* Table 1.8.2.

Chapter 13

3.3.2	*Reference* Ch 1,4.8 *now reads* Ch 1,4.7.

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Registered office
71 Fenchurch Street, London, EC3M 4BS
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